PLASTIC MATERIAL DIGEST

PVC
(Polyvinyl Chloride) conforming to ASTM D-1784 Class 12454-B, formerly designated Type 1 Grade 1, PVC is the most frequently specified of all thermoplastic materials. It has been used successfully for over 30 years in such areas as chemical processing, industrial plating, chilled water distribution, deionized water lines, chemical drainage, and irrigation systems. PVC is characterized by high physical properties and resistance to corrosion and chemical attack by acids, alkalies, salt solutions and many other chemicals. It is attacked, however, by polar solvents such as ketones, some chlorinated hydrocarbons and aromatics. The maximum service temperature of PVC is 140°F. With a design stress of 2,000 PSI, PVC has the highest long term hydrostatic strength at 73°F of any of the major thermoplastic being used for piping systems. PVC is joined by solvent cementing threading or flanging.

CPVC
(Chlorinated Polyvinyl Chloride) conforming to ASTM D-1784 Class 23447-B, formerly designated Type IV, Grade 1, CPVC has physical properties at 73°F similar to those of PVC, and its chemical resistance is similar to that of PVC. CPVC, with a design stress of 2,000 psi and maximum service temperature of 210°F has, over a period of about 25 years, proven to be excellent material for hot corrosive liquids, hot and cold water distribution and similar applications above the temperature range of PVC. CPVC is joined by solvent cementing, threading or flanging.

Polypropylene
(PP) Polypropylene homopolymer, conforming to ASTM D-4101 Class PP110 B67154, formerly designated Type 1, is a member of the polyolefin family of plastics. Although PP has less physical strength than PVC, it is chemically resistant to organic solvents as well as acids and alkalies. Generally, polypropylene should not be used in contact with strong oxidizing acids, chlorinated hydrocarbons and aromatics. Polypropylene has gained wide acceptance where its resistance to sulfur-bearing compounds is particularly useful in salt water disposal lines, crude oil piping, and low pressure gas gathering systems. Polypropylene has also proved to be an excellent material for laboratory and industrial drainage where mixtures of acids, bases and solvents are involved. Polypropylene is joined by the thermo-seal fusion process, threading or flanging.

PVDF (Kynar®)
(Polyvinylidene Fluoride) PVDF is a strong, tough, and abrasion resistant fluoro carbon material. It resists distortion and retains most of its strength to 280°F. It is chemically resistant to most acids, bases, and organic solvents and is ideally suited for handling wet or dry chlorine, bromine and other halogens. No other solid thermoplastic piping components can approach the combination of strength, chemical resistance and working temperatures of PVDF. PVDF is joined by the thermo-seal fusion process, threading or flanging.

FRP
FIBERGLASS REINFORCED PLASTICS commonly manufactured by hand lay up (HLU) in accordance with CGSB-41-GP-22 in Canada and NBS PS 15-69 in the United States. Also manufactured according to ASTM D-3299 for machine made Filament Wound (FW) construction. FRP constructions are on a custom designed basis allowing the designer to select many different resin systems and laminate constructions. As an engineered system FRP generally displays higher physical properties than thermoplastics with a wide chemical and temperature resistance. Joining methods are by Flanging, Butt and Strap joined or bell and spigot connection.

ARMOURPLASTICS®
These plastics commonly referred to as thermoplastic lined FRP such as PVC, CPVC, PP, PVDF, FEP, ECTFE chemically or mechanically bonded to an FRP structural overlay. This custom engineered system offers the unique properties of the thermoplastic liner with the superior physical properties of the FRP. Joining methods include Flanging, Fusion and Solvent Cementing of the LINER and OVERLAYING WITH FRP.

FPM (Viton® or Florel®)
(Fluoroelastomer) FPM is inherently compatible with a broad spectrum of chemicals. Because of extensive chemical compatibility which spans considerable concentration and temperature ranges, fluorocarbons have gained wide acceptance as a material of construction for butterfly valve O-rings and seats. Fluorocarbons can be used in most applications involving mineral acids (with the exception of HCI), salt solutions, chlorinated hydrocarbons and petroleum oils.

EPDM (EPT)
EPDM is a terpolymer elastomer made from ethylene-propylene diene monomer. EPDM has good abrasion and tear resistance and offers excellent chemical resistance to a variety of acids and alkalines. It is susceptible to attack by oils and is not recommended for applications involving petroleum oils, strong acids (with the exception of HCI), or strong alkalines.

Teflon®
PTFE (Polytetrafluoroethylene) has outstanding resistance to chemical attack by most chemicals and solvents. PTFE has a temperature rating of -200°F to +500°F. PTFE, a self-lubricating compound, is used as a seat material in Fabco Ball Valves.

Neoprene® (CR)
Neoprene® was the first commercial synthetic rubber. It is a moderately oil-resistant material with good ozone-resisting properties. Neoprene is not recommended for use with aromatic hydrocarbons or chlorinated solvents. It is specifically recommended for use with higher concentrations of sodium hydroxide. It can be used in continuous service up to 180°F.

THERMOPLASTIC FABRICATION INTRODUCTION

INTRODUCTION

The preparation of thermoplastics for assembly by welding or other fastening methods is similar to the procedures used in metal fabrication. The pieces are laid out, cut, machined and joined with the same tools, equipment, and skills employed in the metal working trades. There are, however, special forming requirements for thermoplastics, not encountered in metal work. The degree of skill and the quality of preparatory work in layout and in various machining operations on components for fit up are very important in assuring accurate assembly and successful fabrication.

Fabrication of thermoplastics covers a wide field of operations on sheet, rod, tube, and special shapes in making them into finished products: cutting, sawing, machining, forming and joining or fastening together for the completed object. Machining may include beveling, routing, grinding, turning, milling, drilling, tapping, and threading. Once the different parts are shaped, they then may have to be joined.

Assembly techniques include use of self-tapping screws, threaded inserts, press fitting, snap fitting, cold heating, heat joining (like hotplate welding, hot-wire welding, induction heating, thermal-impulse heating, resistance-wire welding, or hot flaring, spin welding), cementing, and hot gas welding. Each operation requires its own tools and equipment.

CUTTING

Thermoplastic rods and shapes can be readily cut with an ordinary hand hacksaw, or power saws can be used. Using a circular power saw, a cutting speed of 6,000 rpm. Using hand pressure is recommended. With bandsaws, this should be reduced to 3,600 fpm with hand pressure. Under some circumstances a lathe can be used. Best results are obtained with fine-toothed saw blades (6 to 9 teeth per in.) and little or no set (maximum 0.025 in.).

THREADING

Thermoplastic pipe, rod and shapes can easily be threaded using either standard hand pipe stocks or power operated equipment. For optimum results in threading, use of new taps and dies is recommended; but in any case they should be clean and sharp and maintained in good condition. Power threading machines should be fitted with dies having 5° negative front rake and ground especially for this application, tapered guide sleeves are not required. For hand stocks, the dies should have a negative front rake angle of 5 to 10°. Dies which have been designed for use on brass or copper pipe may be successfully used. Carboloy dies give longer service.

Taps should be ground with a 0 to 10° negative rake, depending upon the size and pitch of the thread. Die chasers should have a 33° chamfer on the lead: a 10° front or negative rake; and a 5° rake on the back of relief edge. Self-opening die heads and collapsable taps, power threading machines and a slight chamfer to lead the tap or dies will speed production, however, taps and dies should not be driven at high speeds or with heavy pressure.

A tapered plug should be inserted into tubular ends when threading to hold the pipe round and to prevent the die from distorting or digging into the pipe wall. This insures uniform circumferential depth of threads. Pipe for threading should be held in a pipe vice since sawtooth jaws will leave marks. Thermoplastic materials are readily threaded without use of external lubricants. However, ordinary lubrication or cutting oil will be beneficial to the operation. In a pipe-threading machine, water soluble oil or plain cold water is used. Clearing of cuttings from the die is strongly recommended.

HEAT WELDING

The most important and most versatile of welding methods is hot gas and air welding which, in principle, is similar to oxyacetylene welding of metals, but with a difference in the technique involved. Specialized welding equipment has been developed in which the pressure and the rate and area of heating are precisely controlled in order to provide strong, tight bonds. Welding rods are available in different sizes to suit the individual jobs.

Hot gas welding of thermoplastics is accomplished with a welding torch and tips or tools. It is divided into three basic types of welding: tack welding, hand welding and high speed welding. Each type requires different tips or high speed tools.

FUSION WELDING

Industrial thermoplastics such as PVC, PP, PE, and PVDF can be fusion welded using modern temperature and pressure controlled fusion equipment. This relatively simple equipment is available to fuse PIPE and Tube products to 24” diameter. SHEETS and Plates can also be fused using micro processor controlled fusion machines. Weld efficiency, when using modern equipment, will develop weld strength of up to 98% of the unwelded parent material.

SOLVENT CEMENT WELDING

Cementing is a convenient technique for bonding PVC and CPVC (High-Temp) stock. Surfaces to be cemented must be clean and dry. They should be cut square and smooth and wiped clean of dirt, grease, etc. with a small amount of Fabco Pipe Cleaner.

When solvent-cementing, it is important to have close clearances between the surfaces to be joined. Solvent- cement should be applied with an ordinary small paint brush to each member. (Do not use synthetic hair brushes). Then the cemented surfaces should immediately be pushed snugly together. After the cemented joint has been pressed together the initial set takes place within several minutes.

Handling strength, however, is not developed for approximately 30 minutes. Relative motion between the cemented surfaces during the initial set period is undesirable. It is good practice to apply no more than 10% of the rated stress for four hours. Full strength of the joint is developed after about 48 hours.

FLANGING

One of the earliest methods of joining thermoplastics piping, flanging continues to be used extensively for process lines. Thermoplastic flanges and flanged fittings are available in a full size range and may be attached to pipe by solvent welding, by threading, or by thermal bonding, as required by the particular thermoplastics material.

MACHINING, CUTTING AND SAWING

Thermoplastics may be turned, threaded, grooved, milled, or polished to very close tolerances, with the same tools as are used for wood or metal.

The only requirement for machining of plastic that differs from metal machining is compensation for heating up of materials due to its poor heat-conductivity. The limitation of heat build-up is accomplished by use of sharp, high-speed tools, streams of air or water/soda cooling, and proper machine feeds.

In machining plastics on a lathe, tool bits should be sharpened as for machining brass. The tool should be ground with a front clearance of 10°, a 2° negative back-rake and no side rake. The tool should have a 10° side-clearance. Chips should be blown or washed away from the work to reduce frictional heat to a minimum.

The piece is set up in the lathe for turning or thread cutting as in metal work but with special protection provided for the plastic where it is held in the chuck jaws. The plastic should be wrapped in several heavy layers of heavy cardboard, held in place by masking tape, before being inserted into chuck.

A cutting speed of 200 fpm is recommended. Lathe speed for machining different diameters of plastic can be calculated as: 4 times the cutting speed (fpm) divided by the diameter of the plastic in inches. Example: With a plastic rod 1- in. diameter, the lathe speed would be 200 times 4 divided by 1 or 800 rpm. Light cuts are recommended - 0.030 to 0.060 in. cross-feed at a time.

In sawing plastic sheet, there is likely to be concentrated heat build-up in the saw blades. To allow for this, the blade used should be selected in accordance with the gauge of the material. The saw blade for cutting thicker materials should be heavier and should be hollow ground. The saw should make a slicing cut in the material: to do this, the teeth should have negative rake, with little or no set. The rate of feed should be very slow. The blade of a circular saw should just show through the material. If it extends too far through, it will increase the heat build-up, by increasing friction.

In cutting polyethylene and polypropylene on a circular saw, the saw blade required is different from that used in cutting PVC. PE and PP do not require a hollow ground blade and are cut by a well-set saw blade. Shears can be used for cutting of light gauge thermoplastic sheets. All shearing should be accomplished at room temperature. A cold sheet will crack or shatter. A 1/8-in. sheet of Type 1 PVC can be sheared easily. Heavier-gauge Type 1 PVC will tend to cut off-square and also show stress marks. Type 2 PVC, PP, PE and modified high impact PVC shear better and to a higher gauge than Type 1 PVC. In drilling plastics, the same problems are experienced as in drilling metal. The non-conducting characteristics of the material and the heat concentration in the tool must be allowed for. This is accomplished by grinding the drill differently than for drilling metals. If the holes are to be drilled in the fabrication at hand, the drill should be reground to a negative rake and the lip angle increased for 59° to 70°. The margin on the drill should be smooth and highly polished to reduce friction. Drilling speeds should be reduced: 50 to 150 rpm is a safe range, with 120 rpm being optimum. Very slow feeds should be used.

Guidelines For Processing and Machining Plastics

General Remarks

- Non-reinforced thermoplastics can be machined with cutting tools of highspeed steel. For reinforced materials, hard metal tools are required.
- In all cases, only properly sharpened tools are to be used.
- Due to the poor thermal conductivity of plastics, provision has to be made for good heat dissipation. Heat is best dissipated via the chips.

Dimensional Stability

- Dimensional stability of parts is conditional on stress-relieved, semi-finished materials which have to be annealed. The heat generated by the cutting tool otherwise inevitably leads to the release of processing stresses and deformation of the part. In the case of high material removal volumes, intermediate heating may be necessary after the main machining operation so as to remove the arising thermal stresses.
- Materials with high moisture absorption (e.g. polyamides) may require conditioning before machining.
- Plastics require larger finishing tolerances than metals. Furthermore, allowance has to be made for the many times greater thermal expansion.

Machining Operations

1. Turning

Guide values for cutting tool geometry are given in the table. For particularly high quality surface finishes, the tip is to be shaped as a broad-nosed finishing tool as shown in Figure 1.

For cutting off, the tool should be ground to the profile shown in Figure 2 so as to avoid a remaining stump.

On thin walled and particularly flexible workpieces, on the other hand, it is better to work with tools that are ground to a knife-like cutting geometry. Figures 3 and 4.

2. Milling

For plane surfaces, face milling is more economical than peripheral milling. For perpheral milling and profiling, the cutting tools should not have more than two cutting edges so that vibrations due to the number of teeth are kept to a minimum and chip widths are sufficiently large.

Optimum removal rates and surface finish are obtained with single-point tools.

3. Drilling and boring

As a general rule it is possible to use twist drills; these should have an angle of twist of 12-16° and very smooth helical flutes for good chip removal. Larger diameters should be rough-drilled or produced by trepanning or internal turning.

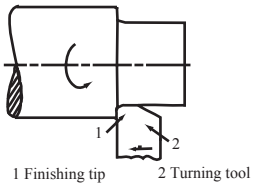
On drilling into solid material, care must be taken to ensure that the tools are properly sharpened; otherwise, the developing compressive strain can build up and cause the material to split.

Reinforced plastics possess higher residual processing stresses with lower impact strength than unreinforced plastics and are thus particularly susceptible to cracking. Where possible, these should be heated to about 120°C before drilling or sawing (heating time approximately 1 hour per 10 mm cross-section). This procedure is also recommended in the case of polyamide 6/6.

4. Sawing

Unnecessary generation of heat by friction is to be avoided, since sawing is generally used to cut off thickwalled parts with relatively thin tools. Well-sharpened and heavily crossed sawblades are therefore advised.

Note: The information is only to assist and advise you on current technical knowledge and is given without obligation or liability. All trade and patent rights should be observed. All rights reserved.



1 Finishing tip 2 Turning tool

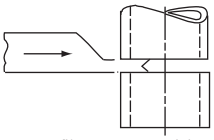


Figure 2: Profile prevents remaining stump

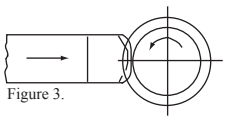


Figure 3.

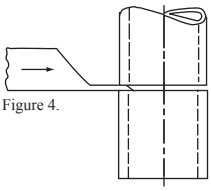
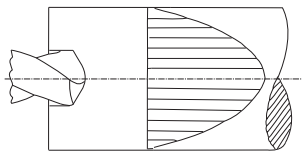
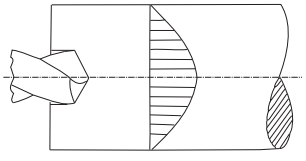


Figure 4.





Machining Operations	Turning				Milling				Drilling and Boring					Sawing				Special Measures
	α Clearance angle (°) y Rake angle (°) X Side angle (°) V Cutting speed ft/min S Feed mils/rev The nose radius r must be at least 0.020 in.				α Clearance angle (°) y Rake angle (°) V Cutting speed ft/min The feed can amount to up to 0.020 in./tooth				α Clearance angle (°) y1 Rake angle (°)b Side angle (°) V Cutting speed ft/min S Feed mils/rev The angle of twist β of the drill bit should be approxi-mately 12 to 16°.					α Clearance angle (°) y Rake angle (°) V Cutting speedft/min t Pitch mils				
Raw Material Group	α	y	X	V	S	α	y	V	α	y1	b	V	S	α	y	V	t	
Polycarbonate	5-10	6-8	45-60	950	4-20	10-20	5-15	950	8-10	10-20	90	150-300	8-12	15-30	5-8	950	115-310	In the case of fluid cooling only use pure water
ABS (Acrylo-nitrile-Butadiene-Styrene)	5-15	25-30	15	650-1600	8-20	5-10	0-10	950-1600	8-12	10-30	90	150-650	8-12	15-30	0-5	950	75-310	In the case of fluid cooling only use pure water
PPS (Polyphe-nylene Sulfide)	6-8	2-8	45-60	500-650	4-20	15-30	6-10	250-350	6	5-10	120	250-300	4-12	15-30	10-15	600-950	115-195	Preheat to 240°F before drilling or sawing
Polysulfone	6	0	45-60	1150-1300	4-12	2-10	1-5	800-1600	3-10	10-20	90	50-250	4-12	15-30	0-4	1600	75-195	Preheat to 240°F before drilling or sawing
PVDF (Poly-vinylidene Fluoride)	10	5-8	10	500-1600	4-12	5-15	5-15	800-1600	10-16	5-20	130	500-650	4-12	20-30	5-8	950	75-195	
Nylon 6/6	6-10	0-5	45-60	800-1600	4-20	10-20	5-15	800-1600	5-15	10-20	90	150-500	4-12	20-30	2-5	1600	115-310	
Acetal	6-8	0-5	45-60	950-1950	4-16	5-15	5-15	800-1600	5-10	15-30	90	150-650	4-12	20-30	0-5	1600-2600	75-195	
PET (Polyethyl-ene Terephthalate)	5-10	0-5	45-60	950-1300	8-16	5-15	5-15	950	5-10	10-20	90	150-300	8-12	15-30	5-8	950	115-310	Preheat to 240°F before drilling or sawing
Acetal Homopo-lymer (DEL-RIN®)	6-8	0-5	45-60	950-1950	4-16	5-15	5-15	800-1600	5-10	15-30	90	150-650	4-12	20-30	0-5	1600-2600	75-195	
PPO (Polyphe-nylene Oxide) (NORYL®)	5-10	6-8	45-60	950	4-20	10-20	5-15	950	8-10	10-20	90	150-300	8-12	15-30	5-8	950	115-310	In the case of fluid cooling only use pure water
Polyetheretherke-tone (PEEK)	6-12	5	45-60	950	15	5-15	5-15	550-750	12	10-20	118	400	2-8	15-30	10-15	600-950	115-195	Preheat to 240°F before drilling or sawing
Polyetherimide (ULTEM®)	15	5	5	1000-2000	5-20	15	5	650-1300	5-10	5-20	70-90	300	5-15	15-30	5-10	3000-5000	100	In the case of fluid cooling only use pure water
Reinforced Engi-neering Plastics*	6-8	2-8	45-60	500-650	4-20	15-30	6-10	250-350	6	5-10	120	250-300	4-12	15-30	10-15	600-950	115-195	Use hard metal cutting tools

INSTALLATION INSTRUCTIONS

INTRODUCTION

SCOPE

One of the more important features of industrial thermoplastics is the ease with which they lend themselves to a variety of fabricating techniques. This versatility, plus the wide selection of piping components now available, make possible fast and economical installation, maintenance and modification of industrial piping systems. It is the objective of this section to provide detailed instructions on all known techniques of joining, maintaining and handling thermoplastics in order to permit maximum integrity of your piping system.

SOLVENT WELDING

The generally preferred method of joining rigid thermoplastics such as PVC and CPVC is solvent welding. This process gives a stronger joint than threading and is also considered faster and simpler. Additionally, solvent welding permits the use of thinner walls when compared to threaded connections for equivalent pressure ratings.

THERMO-SEALING (SOCKET FUSION)

Polypropylene (PP), a thermoplastic polyolefin and PVDF (Kynar), cannot be dissolved by even the strongest of organic solvents. Since solvent attack (or bite) by dissolution is necessary to effect a solvent cement bond with thermoplastics, it is not possible to join polypropylene or PVDF by solvent cementing. Therefore, polypropylene and PVDF pressure systems can only be joined using heat fusion techniques. A thermal sealing procedure is used when joining using heat fusion techniques. A thermal sealing procedure is used when joining 1/2” through 4” sizes. When joining 6” polypropylene systems, which are recommended for drainage applications only, a fillet welding procedure is utilized.

THREADING

Threaded joints are sometimes used when a piping system must be dismantled for occasional cleaning or modifications. Since threading results in a reduction in the effective wall thickness of the pipe, the pressure rating of threaded pipe is reduced to one-half that of unthreaded pipe, ie. pipe joined by solvent cementing or thermal sealing. This reduction in wall thickness resulting from threading can seriously affect the pressure carrying capability and mechanical strength of Schedule 40 or lighter pipe and therefore, only Schedule 80 or heavier pipe should be threaded when the pipe is used for pressure applications. Also, threading is not recommended for plastic pipe above 4 inches in diameter nor is it recommended for pressure polypropylene piping systems.

FLANGING

One of the earliest methods for joining thermoplastic piping, flanging continues to be used extensively for process lines. Thermoplastic flanges and flanged fittings are available in a full size range and mat be attached to pipe by solvent welding, by threading, or by thermal sealing, as required by the particular thermoplastic material.

STORAGE AND HANDLING OF THERMOPLASTIC PIPING COMPONENTS

SCOPE

Industrial thermoplastic piping components are designed and manufactured for use in severe duty systems involving the transport of aggressive liquids. In order to ensure their integrity, once installed, they must be handled with reasonable care prior to installation.

STORAGE

1. **Pipe** - When pipe is received in standard lifts it should remain in the lift until ready for use. Lifts should not be stacked more than three high and should always be stacked wood on wood. Loose pipe should be stored on racks with a minimum support spacing of three feet. Pipe should be shaded but not covered when stored outside in high ambient temperatures. This will provide for free circulation of air and reduce the heat build-up due to direct sunlight exposure.
2. **Fittings** - Fittings should be stored in their original cartons to keep them free of dirt and reduce the possibility of damage. If possible, fittings should be stored indoors.
3. **Solvent Cements and Primers** - Solvent cements have a definite shelf life and each can and carton is clearly marked with a date of manufacture. Stock should be rotated to ensure that the oldest material is used first. Primer does not have a shelf life but it is good practice to rotate this stock also. Solvent cements and primers should be stored in a relatively cool shelter away from direct sun exposure.

CAUTION: SOLVENT CEMENTS AND PRIMERS ARE COMPOSED OF VARIOUS SOLVENTS AND REQUIRE SPECIAL CONDITIONS FOR STORAGE. BECAUSE OF THEIR FLAMMABILITY THEY MUST NOT BE EXPOSED TO IGNITION, HEAT, SPARKS OR OPEN FLAMES.

HANDLING

1. **Pipe and Fittings** - Care should be exercised to avoid rough handling of thermoplastic pipe and fittings. They should not be dragged over sharp projections, dropped or have objects dropped upon them. Pipe ends should be inspected for cracks resulting from such abuse. Transportation by truck or pipe trailer will require that the pipe be continuously supported and all sharp edges on the trailer bed that could come in contact with the pipe must be padded.
2. **Solvent Cements and Primers** - Keep containers for solvent cements tightly closed except when in use. Avoid prolonged breathing of solvent vapors, and when pipe and fittings are being joined in partially enclosed areas use a ventilating device to attenuate vapor levels. Keep solvent cements, primers and cleaners away from all sources of ignition, heat, sparks and open flames. Avoid repeated contact with the skin by wearing proper gloves impervious to the solvents. Application of the solvents or cements with rags and bare hands is not recommended; natural fiber brushes and other suitable applicators can produce satisfactory results.

DANGER: Extremely flammable. Vapor harmful. May be harmfulif swallowed. May cause skin or eye irritation.

INSTALLATION INSTRUCTIONS

SOLVENT WELDING INSTRUCTIONS FOR PVC & CPVC PRESSURE PIPE SYSTEMS

SCOPE

The solvent welding procedure detailed herein applies to all Fabco Polyvinyl Chloride (PVC) and Chlorinated Polyvinyl Chloride (CPVC) pressure piping systems including molded fittings and valves. Belled end pipe can also be joined in this manner. FABCO TECHNICAL SERVICES is available for additional solvent welding guidance and recommendations.

Joining Equipment and Materials

- Cutting Tool
- Rags (nonsynthetic, ie., cotton)
- Deburring Tool
- Cement and Primer Applicators
- Applicator Can or Bucket
- Purple Primer P-70
- Solvent Cement 705, 707, 711, 717, 719, 714
- Tool Tray
- Notched Boards

TYPES OF CEMENT AND PRIMER

1. FABCO WELD-ON Light Duty Industrial Grade PVC Solvent Cement #705 is for use with Schedule 40, DWV and Class (SDR rated) piping through 6".

2. FABCO WELD-ON Heavy Duty Gray Industrial Grade PVC Solvent Cement #711 is for use with Schedule 80 piping through 6". The gap-filling high viscous formulation may also be used for Schedule 40, drainage, conduit and all Class (SDR rated) piping through 6".

3. FABCO WELD-ON Extra Heavy Duty Gray Industrial Grade PVC Solvent #717, #719 Cement is for use with all PVC piping, especially 6" and larger. When applied, the very heavy bodied formulation maintains a generous coating with minimum change in thickness over the entire pipe circumference.

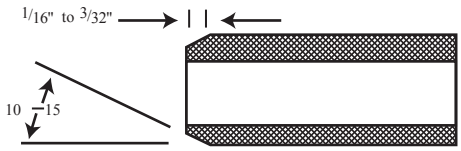
4. FABCO WELD-ON Heavy Duty Light Gray Industrial Grade #714 CPVC Solvent Cement is for use with all sizes of Schedule 40 and 80 CPVC piping. It may be used in any industrial or commercial applications suitable to CPVC.

5. FABCO Purple Primer #P70 is for use with all PVC and CPVC piping applications. (Purple container label.) All of the products above are listed by IAPMO for pressure and drainage applications, and they are NSF approved for potable water. NOTE: Do not take shortcuts - follow instructions completely.

PREPARATION FOR JOINING

1. **Cutting** - Plastic pipe can be easily cut with a power or hand-saw, circular or band saw. For best results, use fine-toothed blade (16-18 teeth per inch) with little or no set (maximum 0.025 inch). A circumferential speed of about 6,000 ft./ min. is suitable for circular saws; band saw speed should be approximately 3,000 ft./min. Carbide-tipped blades are preferable when quantities of pipe are to be cut. To ensure square-end cuts, a miter box, holddown or jig should be used. Pipe or tubing cutters can be used for smaller diameter pipe when the cutting wheel is specifically designed for plastic pipe.

2. **Deburring and Beveling** - All burrs, chips, filings, etc., should be removed from both the pipe I.D. and O.D. before joining. Use a knife, deburring tool or half-round, coarse file to remove all burrs. All pipe ends should be beveled to approximately the dimensions shown below for ease of socketing and to minimize the chances of wiping the solvent cement for the I.D. of the fitting as the pipe is socketed:



The beveling can be done with a coarse file or a beveling tool.

3. **Fitting Preparation** - Prior to solvent welding, all fittings and couplings should be removed from their cartons and exposed for at least one hour to the same temperature conditions as the pipe in order to assure that they are thermally balanced before joining.
4. **Cleaning** - Using a clean, dry cotton rag, wipe away all loose dirt and moisture from the I.D. and O.D. of the pipe end and the I.D. of the fitting. DO NOT ATTEMPT TO SOLVENT WELD WET SURFACES.

DANGER: Solvent cements and primer are extremely flammable and vapor harmful. Keep away from heat, sparks and open flame. Use only with adequate ventilation.

Harmful if swallowed. Avoid prolonged breathing of vapor. Avoid contact with eyes, skin and clothing. Causes eye irritation. Repeated or prolonged skin contact causes skin irritation. Close container after each use.

FIRST AID: In case of skin contact, flush with water; for eyes, flush with water for at least 15 minutes and seek medical attention. Wash contaminated clothing before reuse. If swallowed, DO NOT INDUCE VOMITING, call a Physician immediately.

INSTALLATION INSTRUCTIONS

PRIMING

The function of purple primer is to penetrate and soften the bonding surfaces of PVC and CPVC pipe and fittings. It is a product that penetrates rapidly. It is very effective on the hard-finished, high gloss products now being produced. Priming is a 3-step process as follows:

1. Using a natural bristle brush about one-half the width of the pipe diameter to be jointed, apply Purple Primer freely to the inner fitting socket. A rag is not recommended as repeated contact with skin may cause irritation or blistering. Keep the surface wet by maintaining a brushing motion of the applicator over the entire surface for five to fifteen seconds. Re-dip applicator as necessary but avoid puddling inside the fitting.

2. Apply primer to the pipe surface in the same manner making sure that the length of pipe evenly brushed is at least equal to the fitting socket depth.
3. Re-apply primer to the fitting socket. Alternate applications of Purple Primer, start with the female component.

For checking penetration, you should be able to scratch or scrape a few thousandths of the primed surfaces away. Repeated applications to either or both surfaces may be necessary. Weather conditions do affect priming action. In cold weather more time is required for proper penetration. NOTE: The pipe ends can be rested on notched boards to keep them clean and for ease of solvent cement application.

Recommendations for Solvent Cement/Primer Application

NOMINAL PIPE SIZE (Inches)	BRUSH WIDTH* (Inches)	ROLLER LENGTH (Inches)	DAUBERS (Comm./Res Piping Only)	
			Pressure Joints	Non-Press. Joints
1/4	1/4	Not Recommended	N/A	N/A
1/2	1/2	Not Recommended	3/4" Diameter	3/4" Diameter
3/4	1/2	Not Recommended	3/4" Diameter	3/4" Diameter
1	1/2	Not Recommended	3/4" Diameter	3/4" Diameter
1 1/4	1	Not Recommended	1-1/2 Diameter	1-1/2 Diameter
1 1/2	1	Not Recommended	1-1/2 Diameter	1-1/2 Diameter
2	1	Not Recommended	1-1/2 Diameter	1-1/2 Diameter
2 1/2	1 1/2	Not Recommended	Not Recommended	1-1/2 Diameter
3	1 1/2	Not Recommended	Not Recommended	1-1/2 Diameter
4	2	3	Not Recommended	1-1/2 Diameter
6	3	3	Not Recommended	1-1/2 Diameter
8	4	7	Not Recommended	Not Recommended
10	4 to 6	7	Not Recommended	Not Recommended
12	4 to 6	7	Not Recommended	Not Recommended

Natural bristle brushes should always be specified. It is recognized that the recommended brush width may not always be readily available. However, the selection should come as close as possible to the recommended width in order to ensure complete coverage with a minimum number of brush strokes.

SOLVENT CEMENT APPLICATION

Before the primer dries, use a second applicator (see chart on preceding page for specific recommendations) to apply solvent cement in a 3-step process as follows:

1. Cover the pipe liberally with solvent cement for a length at least equal to that of the fitting socket depth. It is important not to be stingy with cement.

2. Continuing with alternate surface application, coat the fitting socket thoroughly with a medium layer of solvent cement. Avoid puddling in the socket. On belled end pipe, do not coat beyond the socket depth or allow cement to run beyond the bell.

3. Put a second coat of cement on the pipe. This completes the six steps of alternate surface applications for a joint – three of primer and three of solvent cement – starting with the female component. Cement layers must be without voids and sufficient to fill any gaps in the joints.

JOINING

1. Immediately upon finishing cement application and before it starts to set, insert the pipe to the full socket depth while rotating the pipe or fitting a 1/4 turn to ensure complete and even distribution of the cement. Hold joint together for a minimum of 10 to 15 seconds to make sure that pipe does not move or back out of the socket.

2. For pipe sizes 6" and larger, a joining crew consisting of two men is recommended and the following additional steps necessary:
   a. Rotation of the pipe in the fitting may be omitted.
   b. Hold joint together for 1 to 3 minutes depending on pipe size.
   c. As an aid for joining in these larger sizes, it is recommended that a come-along or pipe joining tool be used.

EXCESS CEMENT

Immediately after joining and before joint is set, gently place it back onto a level surface, wipe off all excess cement from the circumference of the pipe and fitting.

JOINT INTEGRITY

PVC and CPVC piping joint integrity depends greatly upon following exactly and by intent Fabco's specific handling, inspection, storage, shipping, fabrication, installation, testing and operating instructions. Joint integrity also depends greatly upon an infinitely wide, unpredictable and uncontrollable set of product and environmental conditions that go into determining the length of joint drying times before it may be moved; handled; low, high or working pressure tested. These conditions include size of pipe, surface temperature of the joint, dry joint interference fit and relative humidity. Drying times will be faster with smaller pipe, higher surface temperatures, tighter interference fits and lower relative humidity. Drying times will be slower when conditions are reversed.

Because of these almost infinite and completely unpredictable variety of drying conditions that can exist from job to job and from time to time, FABCO only specifically recommends for its PVC and CPVC products the below solvent welding joining temperatures and joint drying times:

1. The actual joining should not be done in atmospheric temperatures below 40°F or above 90°F when exposed to direct sunlight.
2. FABCO recommends that 72 hours of joint drying time should elapse for all sizes of pipe and drying temperatures before the joint is subjected to any appreciable internal or external pressure on a full time basis.

HANDLING

During the initial setting of the cement, which begins about two minutes after application (on small sizes), be careful not to move or disturb the joint.

FABCO offers, as a non-liability supplier, the following drying times as a guide in aiding the installer, engineer, owner or other decision making party in deciding at his own risk when the joints are sufficiently dry for movement; handling; low pressure, initial joint testing, application of high pressure tests and introduction of working pressure. These drying times are based upon a combination of past field experience and laboratory tests.

PVC and CPVC Joint Movement Times

NOMINAL PIPE SIZE	HOT WEATHER 90° - 150° F Surface Temperature	MILD WEATHER* 50° - 90° F Surface Temperature	COLD WEATHER* 10°- 50°F Surface Temperature
1/4" - 1 1/4"	12 Min.	20 Min.	30 Min.
1-1/2" - 2-1/2"	30 Min.	45 Min.	1 Hr.
3" - 4"	45 Min.	1 Hr.	1 Hr. & 30 Min.
6" - 8"	1 Hr.	1 Hr. & 30 Min.	2 Hrs. & 30 Min.
10" - 12"	2 Hrs.	3 Hrs.	5 Hrs.

*The temperatures above are drying temperatures and should not be confused with atmospheric, joining temperatures recommendations and limitations. See section on "JOINT INTEGRITY".

PRESSURE TESTING

CAUTION: AIR OR COMPRESSED GAS IS NOT RECOMMENDED AS A MEDIA FOR PRESSURE TESTING OF PLASTIC PIPING SYSTEMS.

1. **Initial Joint Testing -** Initial joint testing of PVC and CPVC pipe could possibly be accomplished to 10% of its hydrostatic pressure rating after the below drying times:

NOMINAL PIPE SIZE	HOT WEATHER 90° - 150° F Surface Temperature	MILD WEATHER* 50° - 90° F Surface Temperature	COLD WEATHER* 10°- 50°F Surface Temperature
1/2" - 1 1/4"	4 Hrs.	5 Hrs.	7 Hrs.
1-1/2" - 2-1/2"	6 Hrs.	8 Hrs.	10 Hrs.
3" - 4"	8 Hrs.	18 Hrs.	24 Hrs.
6" - 8"	12 Hrs.	24 Hrs.	48 Hrs.
10" - 12"	18 Hrs.	36 Hrs.	72 Hrs.

PVC and CPVC Joint Drying Times at 10% Pressure Testing

*The temperatures above are drying temperatures and should not be confused with atmospheric joining temperature recommendations and limitations. See section on "JOINT INTEGRITY".

INSTALLATION INSTRUCTIONS

2. **High Pressure Testing -** The PVC and CPVC pipe can be pressure tested up to 100% of its hydrostatic pressure rating after drying times listed in the table which follows:

NOMINAL PIPE SIZE	HOT WEATHER 90° - 150° F Surface Temperature	MILD WEATHER* 50° - 90° F Surface Temperature	COLD WEATHER* 10°- 50°F Surface Temperature
1/2" - 1 1/4"	4 Hrs.	5 Hrs.	7 Hrs.
1-1/2" - 2-1/2"	6 Hrs.	8 Hrs.	10 Hrs.
3" - 4"	8 Hrs.	18 Hrs.	24 Hrs.
6" - 8"	12 Hrs.	24 Hrs.	48 Hrs.
10" - 12"	18 Hrs.	36 Hrs.	72 Hrs.

PVC and CPVC Joint Drying Times for 100% Pressure Testing The temperatures above are drying temperatures and should not be confused with atmospheric, joining temperature recommendations and limitations. See section on "JOINT INTEGRITY".

3. **Full-Time Working Pressure -** PVC and CPVC joints may be introduced to maximum working pressure on a full-time basis after approximately four times the drying time shown above for 100% pressure testing.

DO'S AND DON'TS

Do:
- Use the proper applicator (See chart for specific recommendations).
- Use proper type of solvent cement for the job.
- Apply the cement while the primer is still wet.
- Follow the instructions completely.

Don't:
- Attempt to solvent weld under the following conditions:

  1. If it is raining
  2. If atmospheric temperature is below 40°F.
  3. If under direct exposure to sun at atmospheric temperatures above 90°F.

- Discard empty cans of solvent, primer or rags in trench or near piping. Concentrated fumes or dripping cement or primer can cause piping failure.

HOT WEATHER CEMENTING

Since cement contains a solvent, certain precautions or steps should be taken when the atmospheric temperature is above 90°F to avoid excessive evaporation of the solvent from the cement just prior to joining. Such evaporation will cause the cement to prematurely set before joining, thus, adversely affecting the joint integrity. Use one or a combination of the below to reduce the chances of this condition occurring:

1. Shade or shelter the joint surfaces from direct exposure to the sun's rays for at least one hour prior to joining and during the joining process.
2. Make cement joints during early morning hours.
3. Apply cement quickly. On 6" and larger pipe, it is recommended that two men apply cement to pipe surface while the third applies it to the fitting socket.
4. Join pipe to fittings as quickly as possible after applying cement.

COLD WEATHER CEMENTING

Because the solvents in the cement will not evaporate as readily when the temperature is below 40°F, the pipe joints will not set up as rapidly in cold weather. If solvent cementing must be done when the temperature is below 40°F, the following suggestions are offered:

1. Store pipe, fittings, cement and primer in a heated area.
2. Pre-fab as much of the system as possible in a heated work area.
3. Joints that must be made outside should be protected with a portable shelter and heated with indirect heat to surface temperatures about 40°F prior to joining. The shelter and heat should remain in place for at least two hours after joint assembly.
4. Pipe and fittings must be dry prior to joining and the joints should be kept dry until the cement has had sufficient time to set.

CAUTION: DO NOT ATTEMPT TO SPEED THE SETTING OR DRYING OF THE CEMENT BY APPLYING DIRECT HEAT TO THE SOLVENT WELDED JOINT. Forced rapid drying by heating will cause the cement solvents to boil off, forming porosity, bubbles and blisters in the cement film.

HANDLING OF PRIMER AND CEMENT

NOTE: Observe the "use prior to" date. Cement has a limited shelf life. Do not permit solvent cement can to stand open. Do not use cement that has dried to the point where it become lumpy and stringy. Throw it away. Do not attempt to thin out sluggish cement with thinner or primer.

ESTIMATED SOLVENT CEMENT REQUIREMENTS

The below estimated PVC and CPVC solvent cement requirements should only be considered as a guideline for usage and could vary according to a wide variety of installation conditions. Further, these estimates should in no way be used to restrict the liberal cement application instructions recommended for the pipe.

INSTALLATION INSTRUCTIONS

Number of Joints Per...*			
PIPE SIZE	PINT	QUART	GALLON
1/2”	130	260	1,040
3/4”	80	160	640
1”	70	140	560
1-1/4”	50	100	400
1-1/2”	35	70	280
2”	20	40	160
2-1/2”	17	34	136
3”	15	30	120
4”	10	20	80
5”	8	16	64
6”	N/R	8	24
8”	N/R	3	12
10”	N/R	N/R	10
12”	N/R	N/R	6

*Each joint represents one socket in a fitting.

THERMO-SEALING (Socket Fusion) INSTRUCTIONS FOR POLYPROPYLENE AND PVDF PRESSURE PIPING SYSTEMS

SCOPE
The socket fusion joining method which is detailed herein applies to all FABCO polypropylene and PVDF pressure piping systems including molded socket fittings, and socket type valve connections. This procedure involves the application of regulated heat uniformly and simultaneously to pipe and fitting mating surfaces so that controlled melting occurs at these surfaces.

All recommendations and instructions presented herein for socket fusion are based upon the use of a Thermo-Seal fusion tool for applying uniform heat to pipe and fittings.

Joining Equipment and Materials
- Cutting tools
- Cotton rags
- Deburring tool
- Thermo-Seal tool
- Electric Model NA with 1/2” - 2” tool pieces or
- Electric Model NB with 1/2” - 4” tool pieces
- Vise

TYPES OF JOINING TOOLS

ELECTRIC MODEL tools are available for making socket fusion joints. They are the preferred socket fusion tools because the thermostatically controlled heat source automatically maintains fusion temperatures within the recommended range.

1. Electric Model NA. This tool which is electrically heated and thermostatically controlled, is used to join polypropylene and PVDF pipe, and valves and fittings in sizes 1/2” through 2”. This unit operates on 110 VAC (6.7 amps; 800 watts) electrically and is fitted with ground wires.

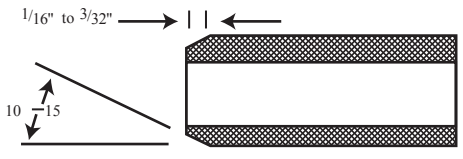
2. Electric Model NB. This tool is also electrically heated and thermostatically controlled and is used to join polypropylene pipe and fittings in sizes 1/2” through 4”. This unit operates on 110 VAC (1.38 amps; 1650 watts) electrically and is fitted with ground wires.

CAUTION: SOCKET FUSION AND FILLET WELDING INVOLVE TEMPERATURES IN EXCESS OF 540°F. SEVERE BURNS CAN RESULT FROM CONTACTING EQUIPMENT OR MOLTEN PLASTIC MATERIAL AT OR NEAR THESE TEMPERATURES.

PREPARATION FOR JOINING

1. Cutting
Polypropylene or PVDF can be easily cut with a power or hand saw, circular or band saw. For best results, use the fine-toothed blades (16-18 teeth per inch). A circumferential speed of about 6,000 ft/min. is suitable for circular saws; band saw speed should be approximately 3,000 ft/min. Carbide-tipped blades are preferable when large quantities of pipe are to be cut. It is important that the pipe ends be cut square. To ensure square end cuts, a miter box, hold down or jig must be used. Pipe or tubing cutters can also be used to produce square, clean cuts, however, the cutting wheel should be specifically designed for plastic.

2. Deburring and Beveling
All burrs, chips, filing, etc., should be removed from both the pipe I.D. and O.D. before joining. Use a knife, deburring tool or half-round, coarse file to remove all burrs. All pipe ends should be beveled to approximately the dimensions shown below for ease of socketing and to minimize the chances of wiping melt material from the I.D. of the fitting as the pipe is socketed. The beveling can be done with a coarse file or a beveling tool.



3. Cleaning
Using a clean, dry cotton rag, wipe away all loose dirt and moisture from the I.D. and O.D. of the pipe end and the l.D. of the fitting. **DO NOT ATTEMPT TO SOCKET FUSE WET SURFACES.**

INSTALLATION INSTRUCTIONS

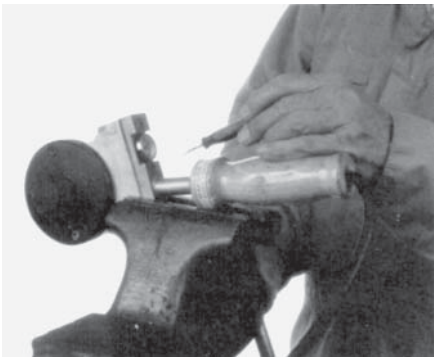
4. Joint Sizing
In order to provide excess material for fusion bonding, polypropylene and PVDF components are manufactured to socket dimensions in which the socket I.D. is smaller than the pipe O.D. Therefore, it should not be possible to easily slip the pipe into the fitting socket past the initial socket entrance depth and in no case should it ever be possible to bottom the pipe in the socket prior to fusion.

Before making socket fusion joints, fittings should be checked for proper socket dimensional tolerances, based on the above discussion, by attempting to insert the pipe into the fitting socket. If a fitting socket appears to be oversize, it should not be used.

5. Planning Construction
Socket fusion joints are more easily made when there is sufficient space to properly secure the Thermo-Seal tool and to maneuver pipe and fittings into the Thermo-Seal tool. Therefore, it is recommended that the piping system be prefabricated, as much as possible, in an area where there is sufficient room to work, and that as few joints as possible should be made in areas where there is limited working space. Mechanical joints such as flanges or unions may be considered in extremely tight areas.

6. Thermo-Seal Tool Set Up

a. Install the male and female tool pieces on either side of the Thermo-Seal tool and secure with set screws.



b. Insert the electrical plug into a grounded 110 VAC electrical source, and allow the tool to come to the proper operating temperature. The tool temperature is read directly from the mounted temperature gauge, and tool temperature can be adjusted by turning the thermostat adjustment screw with a screwdriver. (Counterclockwise) to raise the temperature and clockwise to lower the temperature.)
NOTE: One turn of the adjustment screw will give approximately a 25°F temperature change
IMPORTANT: Good socket fusion joints can be made only when the Thermo-Seal tool is operating at the proper temperature, and only when the length of time that the pipe and fittings remain on the heated tool pieces does not exceed those times recommended for the particular size of pipe and fitting to be joined. Please consult the user manual for your particular system.

Excessive temperatures and excessive heating times will result in excessive melting at and below the surfaces of the fitting socket I.D. and pipe O.D. When the pipe is inserted into the fitting socket, excessive melt material needed for socket fusion will be scraped from the socket wall and into the fitting waterway and the resulting joint will be defective. Low temperatures and insufficient heating times will result in a lack of or incomplete melting making it impossible to make a good socket fusion joint.

MAKING SOCKET FUSION JOINTS

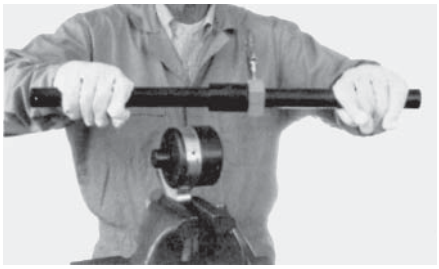
1. Place the proper size depth gauge over the end of the pipe.

2. Attach the depth gauging clamp to the pipe by butting the clamp up to the end of the depth gauge and locking it into place. Then remove the depth gauge.

INSTALLATION INSTRUCTIONS

3. Simultaneously place pipe and fitting squarely and fully on heat tool pieces so that the I.D. of the fitting and the O.D. of the pipe are in contact with the heating surfaces. Care should be taken to insure that the pipe and fitting are not cocked when they are inserted on the tool pieces.

4. Hold the pipe and fitting on the tool pieces for the prescribed amount of time. During this time a bead of melted material will appear around the complete circumference of the pipe at the entrance of the tool piece.



5. Simultaneously remove the pipe and fitting from the tool pieces and immediately insert the pipe, squarely and fully and without purposeful rotation, into the socket of the fitting. Hold the completed joint in place and avoid relative movement between components for at least 15 seconds.

6. Once a joint has been completed the clamp can be removed and preparation for the next joint can be started.

7. The surfaces of the female and male tool pieces are Teflon coated to prevent sticking of the hot plastic. It is important that the tool pieces be kept as clean as possible. Any residue left on the tool pieces should be removed immediately by wiping with a cotton cloth. CAUTION: HOT PLASTIC MATERIAL CAN CAUSE SEVERE BURNS; AVOID CONTACT WITH IT.

Procedures for making good socket fusion joints can be summarized into five basic principles as follows:
1. The tool must be operated at the proper temperature.
2. The pipe end must be beveled.
3. The fitting must be slipped squarely onto the male tool while the pipe is simultaneously inserted into the female tool.
4. The fitting and pipe must not remain on the heat tool for an excessive period of time. Recommended heating times must be followed.
5. The pipe must be inserted squarely into the fitting socket immediately after removal from the heated tools.
6. The Thermo-Seal tool must be kept clean at all times.

PRESSURE TESTING

The strength of a socket fusion joint develops as the material in the bonded area cools. One hour after the final joint is made, a socket fusion piping system can be pressure tested up to 100% of its hydrostatic pressure rating.

CAUTION: AIR OR COMPRESSED GAS IS NOT RECOMMENDED AND SHOULD NOT BE USED AS A MEDIA FOR PRESSURE TESTING OF PLASTIC PIPING SYSTEMS.

FILLET WELDING

SCOPE

The joining procedure covered herein applies only to 6” polypropylene drainage or non-pressure systems. Fillet Welding is not recommended as a primary joining technique for pressure rated systems.

Joining Equipment and Materials
- Cutting and deburring tools
- Plastic welding gun with flexible hose, pressure regulator and

INSTALLATION INSTRUCTIONS

gauge
- Welding and tacking tips
- Compresses air supply or bottled nitrogen (see note below)
- 1/8" welding rod
- Cotton rags

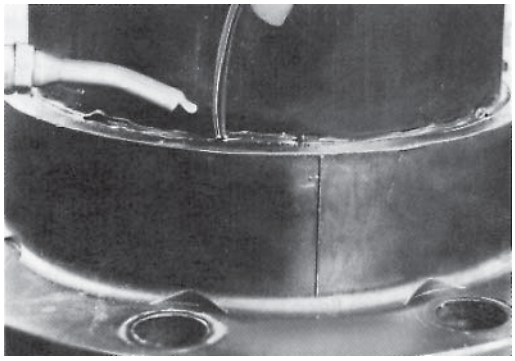
Joining

NOTE: Fillet welding of thermoplastics is quite similar to the acetylene welding or brazing process used with metals. The fundamental differences are that the plastic rod must always be the same basic material as the pieces to be joined; and heated gas, rather than burning gas, is used to melt the rod and adjacent surfaces. Because of its economy, compressed air is normally the gas of choice for most plastic welding. A welding gun which generates its own air supply is frequently desirable for field-made pipe joints where ultimate weld strength is not required. For welding guns which require compressed gas, nitrogen is preferable when the compressed plant air system does not contain adequate drying and filtration (Presence of moisture in the gas stream causes premature failure in the heater element of the welding gun. Impurities in the gas stream, particularly those in oil, may oxidize the plastic polymer, resulting in loss of strength. Polypropylene is known to be affected in this manner).

1. Insert pipe fully and squarely into the fitting after removing all dirt, oil, moisture and loose particles of plastic material from the welding surfaces by wiping with a clean cotton cloth.

2. Adjust the nitrogen/air pressure between approximately 3 and 8 psi and further adjust the pressure as necessary to control both temperature and rate of welding.

NOTE: Tacking required prior to welding. 6" polypropylene joints require a slip fit. Therefore, they must be dry fitted and tack welded to prevent movement of the pipe and fitting prior to the application of welding rod. Special welding gun tips are required for tacking. A low strength bond is accomplished by pulling the heated tacking tip along while directly in contact with the interface of pipe and fitting at an angle of 75° to 80° . Initially, joints are tack-fused at four intervals. Then at least one complete revolution around the joint is made to provide a uniform groove for subsequent rod welding.



3. Holding the polypropylene welding rod at an angle of 75° to the joint and while maintaining pressure on the rod, apply heat uniformly to the rod and the pipe and fitting with an arching motion of the welding torch.

The degree of heating can be controlled by regulating the nitrogen/air flow to the welding gun or by regulating the distance from the tip of the welding gun to the work. Too much heat will over melt the polypropylene material and cause it to splash. Too little heat will result in incomplete fusion. Lay three separate weld beads in the following manner for a full fillet weld:
A. Pipe to fitting
B. Pipe to bead
C. Fitting to bead

When terminating each weld bead, the bead should be lapped on top of (never along-side) itself for a distance of 3/8" to 1/2" insights to hot gas welding see REPAIRING THERMOPLASTIC PIPE JOINTS.

FLANGED JOINTS

SCOPE

Flanging is used extensively for plastic process lines that require periodic dismantling. Plastic flanges are factory flanged valves and fittings in PVC, CPVC, PVDF and polypropylene are available in a full range of sizes and types for joining to pipe by solvent welding, threading or socket fusion as in the case with polypropylene with PVDF.

Gasket seals between the flange faces should be an elastomeric full flat faced gasket with a hardness of 50 to 70 durometer. FABCO can provide neoprene gaskets in the 1/2" through 12" range having an 1/8" thickness. For chemical environments too aggressive for neoprene another resistant elastomer should be used.

When it is necessary to bolt plastic and metal flanges - use flat face metal flanges - not raised face, and use recommended torques shown in table under "INSTALLATION TIPS".

INSTALLATION INSTRUCTIONS

DIMENSIONS

Bolt circle and number of bolt holes for the flanges are the same as Class 150 metal flanges per ANSI B16.5. Threads are tapered iron pipe size threads per ANSI B1.20.1. The socket dimensions conform to ASTM D-2467 which describes 1/2" through 8" sizes and ASTM D439 for Schedule 80 CPVC which gives dimensional data for 1/2" through 6". Internal Fabco specifications have been established for the 10" and 12" PVC patterns and 8" CPVC design, as well as socket designs for polypropylene and PVDF.

PRESSURE RATING

As with all other thermoplastic piping components, the maximum non-shock operating pressure is a function of temperature.

Maximum pressure rating for FABCO valves, unions and flanges is 150 psi. Above 100°F refer to the TEMPERATURE CORRECTION FACTOR CHART HEREIN.

SEALING

The faces of flanges are tapered back away from the orifice area at a 1/2 to 1 degree pitch so that when the bolts are tightened the faces will be pulled together generating a force in the water way area to improve sealing.

INSTALLATION TIPS

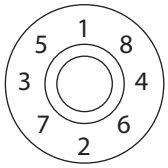
Once a flange is joined to pipe, the method for joining two flanges together is as follows:

1. Make sure that all the bolt holes of the mating flanges match up. It is not advisable to twist the flange and pipe to achieve this.
2. Use flat washers under bolt heads and nuts.
3. Insert all bolts. (Lubricate bolts.)
4. Make sure that the faces of the mating flanges are not separated by excessive distance prior to bolting down the flanges.
5. The bolts on the plastic flanges should be tightened by pulling down the nuts diametrically opposite each other using a torque wrench. Complete tightening should be accomplished in stages and the final torque values shown in the table should be followed for the various sizes of flanges. Uniform stress across the flange will eliminate leaky gaskets.

FLANGE SIZE	RECOMMENDED TORQUE*
1/2 - 1-1/2"	10 - 15 ft.lbs.
2 - 4"	20 - 30 ft.lbs.
6 - 8"	33 - 50 ft.lbs.
10"	53 - 75 ft.lbs.
12"	80 - 110 ft.lbs.

*For a well lubricated bolt with flat washers under bolt head and nut.

The following tightening pattern is suggested for the flange bolts.



6. If the flange is mated to a rigid and stationary flanged object, or a metal flange, particularly in a buried situation where settling could occur with the plastic pipe, the adjacent plastic pipe must be supported or anchored to eliminate potential stressing of the flange joint.

REPAIRING THERMOPLASTIC PIPE JOINTS

SCOPE

The most common method for repairing faulty and leaking joints is hot gas welding at the fillet formed by the junction of the fitting socket entrance and the pipe. Hot gas welding (which is similar to gas welding with metals except that hot gas is used for melting instead of a direct flame) consists of simultaneously melting the surface of a plastic filler rod and the surfaces of the base material in the fillet area while forcing the softened rod into the softened fillet. Welding with plastics involves only surface melting because plastics unlike metal must never be "puddled". Therefore, the resulting weld is not as strong as the parent pipe and fitting material. This being the case, fillet welding as a repair technique is recommended for minor leaks only. It is not recommended as a primary joining technique for pressure rated systems.

WELDING TOOLS AND MATERIALS

- Plastic welding gun with pressure regulator, gauge and hose.
- Filler rod
- Emery cloth
- Cotton rags
- Cutting pliers
- Hand grinder (optional)
- Compressed air supply of bottled nitrogen
- Source of compressed air

WELD AREA PREPARATION

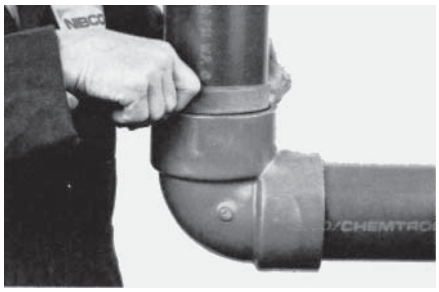
Wipe all dirt, oil and moisture from the joint area. A very mild solvent may be necessary to remove oil.

CAUTION: MAKE SURE THAT ALL LIQUID HAS BEEN REMOVED FROM THE PORTION OF THE PIPING SYSTEM WHERE THE WELD IS TO BE MADE.

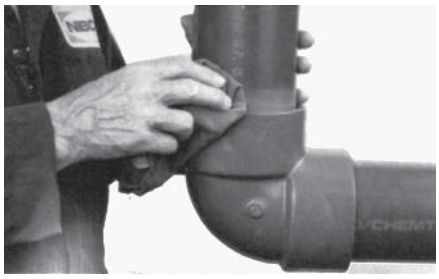
INSTALLATION INSTRUCTIONS

If the weld is to repair a leaking solvent cemented joint, all residual cement, which is easily scorched during welding, must be removed from the fillet by using emery cloth. If the weld is to seal a threaded joint, a file can be used to remove threads in the weld area in order to provide a smooth surface.

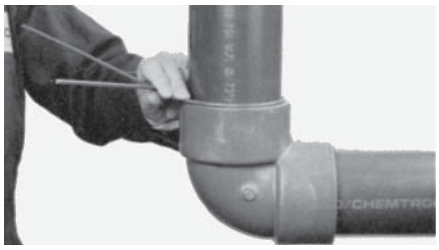
WELDING FAULTY JOINTS



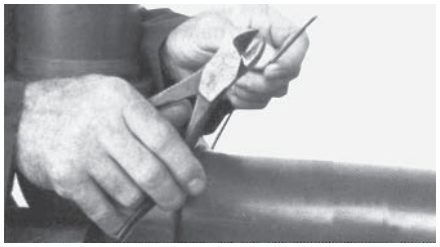
1. Remove residual solvent cement from the weld area using emery cloth. When welding threaded joints, a file can be used to remove threads in the weld area.



2. Wipe the weld area clean of dust, dirt and moisture.



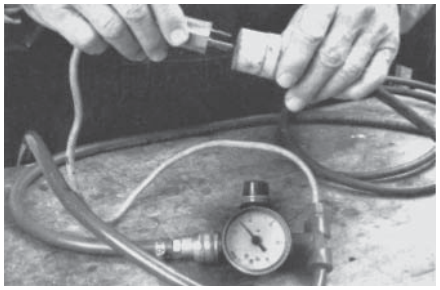
3. Determine the amount for the correct filler rod (see Table No. 1 on page 9-22) necessary to make one complete pass around the joint by wrapping the rod around the pipe to be welded. Increase this length enough to allow for handling of the rod to the end of the pass.



4. Make about a 60° angular cut on the lead end of the filler rod. This will make it easier to initiate melting and will insure fusion of the rod and base material at the beginning of the weld.

5. Welding temperatures vary for different thermoplastic materials (500°F - 550°F for PVC and CPVC, 550°F – 600°F for PP, 575°F - 600°F for PVDF). Welding temperatures can be adjusted for the various thermoplastic materials as well as any desired welding rate, by adjusting the pressure regulator (which controls the gas flow rate) between 3 and 8 PSI.

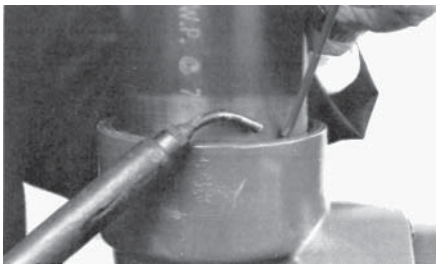
CAUTION: For welding guns which require compressed gas, nitrogen is preferred when the compressed plant air system does not contain adequate drying and filtration. (Presence of moisture in the gas stream causes premature failure in the heater element of the welding gun. Impurities in the gas stream, particularly those in oil, may oxidize the plastic polymer, resulting in loss of strength. Polypropylene is known to be affected in this manner).



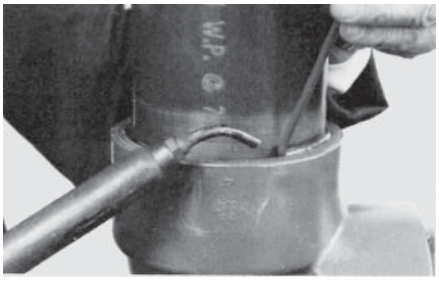
6. With air or an inert gas flowing through the welding torch, insert the electrical plug for the heating element into an appropriate electrical socket to facilitate heating of the gas and wait approximately 7 minutes for the welding gas to reach the proper temperature.

INSTALLATION INSTRUCTIONS

CAUTION: THE METAL BARREL OF THE WELDING TORCH HOUSES THE HEATING ELEMENT SO IT CAN ATTAIN EXTREMELY HIGH TEMPERATURES. AVOID CONTACT WITH THE BARREL AND DO NOT ALLOW IT TO CONTACT ANY COMBUSTIBLE MATERIALS.

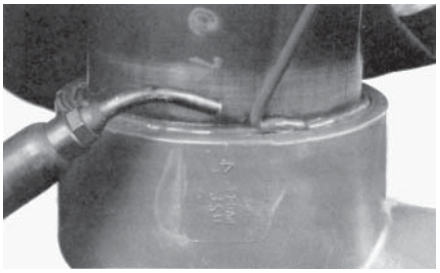


7. Place the leading end of the filler rod into the fillet formed by the junction of the pipe and fitting socket entrance. Holding the filler rod at an angle of 90° to the joint for PVC, CPVC and Kynar, 75° to the joint for polypropylene, pre-heat the surfaces for the rod and base materials at the weld starting point by holding the welding torch steady at approximately 1/4 to 3/4 inches from the weld starting point and directing the hot gas in this area until the surfaces become tacky . While preheating, move the rod up and down slightly so that the rod slightly touches the base materials. When the surfaces become tacky, the rod will stick to the base material.

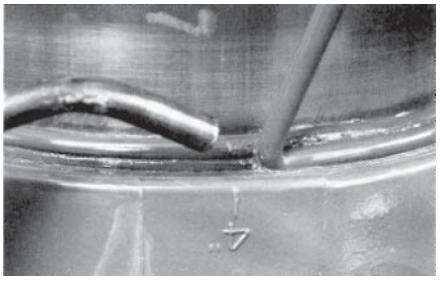


8. Advance the filler rod forward by applying a slight pressure to the rod. Simultaneously applying even heat to the surfaces of both the filler rod and base material by moving the torch with a fanning or arcing motion at a rate of about 2 cycles per second. The hot gas should be played equally on the rod and base material (along the weld line) for a distance of about 1/4 inch from the weld point.

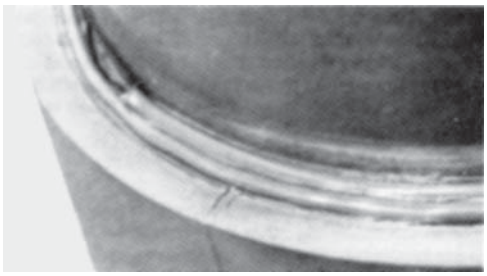
IMPORTANT: If charring of the base or rod material occurs, move the tip of the torch back slightly, increase the fanning frequency or increase the gas flow rate. If the rod or base materials do not melt sufficiently reverse the previously discussed corrective procedures. Do not apply too much pressure to the rod because this will tend to stretch the weld bead causing it to crack and separate after cooling.



9. Since the starting point for a plastic weld is frequently the weakest part of the weld, always terminate a weld by lapping the bead on top of itself for a distance of 3/8 to 1/ 2 inches. Never terminate a bead by overlapping the bead side by side.

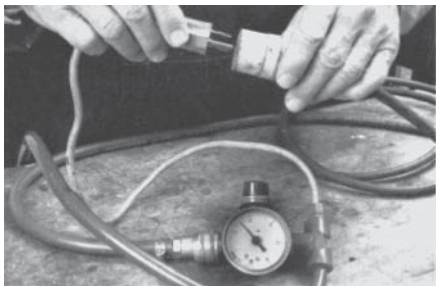


10. When welding large diameter pipe, three weld passes may be required. The first bead should be deposited at the bottom of the fillet and subsequent beads should be deposited on each side of the first bead. When making multiple pass welds, the starting points for each bead should be staggered and ample time must be allowed for each weld pass to cool before proceeding with additional welds.



11. Properly applied plastic welds can be recognized by the presence of small flow lines or waves on both sides of the deposited bead. This indicates that sufficient heat was applied to the surfaces of the rod and base materials to effect adequate melting and that sufficient pressure was applied to the rod to force the rod melt to fuse with base material melt. If insufficient heat is used when welding PVC, CPVC or PVDF, the filler rod will appear in its original form and can easily be pulled away from the base material. Excessive heat will result in a brown or black discoloration of the weld. In the case of polypropylene, excessive heat will result in a flat bead with oversized flow lines.

INSTALLATION INSTRUCTIONS



12. Always unplug the electrical connection to the heating element and allow the welding gun to cool before shutting off the gas or air supply to the gun.

WELDING PRINCIPLES

The procedures for making good thermoplastic welds can be summarized into four basic essentials:

1. Correct Heating – Excessive heating will char or overmelt. Insufficient heating will result in incomplete melting.
2. Correct Pressure – Excessive pressure can result in stress cracking when the weld cools. Insufficient pressure will result in incomplete fusion of the rod material with the base material.
3. Correct angle – Incorrect rod angle during welding will stretch the rod and the finished weld will crack upon cooling.
4. Correct speed – Excessive welding speed will stretch the weld bead and the finished weld will crack upon cooling.

Rod Size and Weld Passes

Filler rod size and the number of weld passes required to make a good plastic weld are dependent upon the size of the pipe to be welded as presented below. Do not use filler rod larger than 1/8" in diameter when welding with CPVC. Also, when welding CPVC, the number of passes for pipe sizes 1" through 2" should be increased to three.

Table 1

Pipe Size	Rod Size	Number of Passes
1/2" - 3/4"	3/32"	1
1" - 2"	3/32"	1 or 3
2-1/2" - 4"	1/8"	3
6" - 8"	1/8" or 5/32"	3
10" - 12"	5/32" or 3/16"	3

Pressure Testing

The strength of a plastic weld develops as it cools. Allow ample time for the weld to cool prior to 100% pressure testing.
CAUTION: Air or compressed gas is not recommended and should not be used as a media for pressure testing of plastic piping systems.

THREADING INSTRUCTIONS FOR THERMOPLASTIC PIPE

SCOPE

The procedure presented herein covers threading of all IPS Schedule 80 or heavier thermoplastic pipe. The threads are National Pipe Threads (NPT) which are cut to the dimensions outlined in (ANSI) B1.20.1 and presented in the table on the following page.

THREADING EQUIPMENT AND MATERIALS

Pipe Dies
Pipe Vise
Threading ratchet or power machine
Tapered plug
Cutting lubricant (soap & water)
Strap wrench
Teflon tape
Cutting and Deburring tools

Pipe Preparation

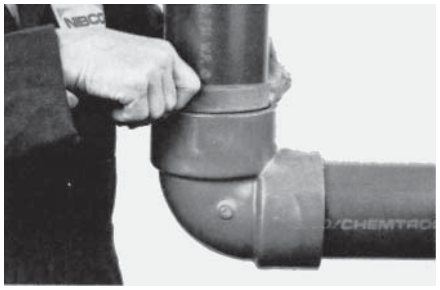
Plastic pipe can be easily cut with a handsaw, power hacksaw, circular or band saw. For best results, use a finetoothed blade (16-18 teeth per inch) with little or no set (maximum 0.025"). A circumferential speed of about 6,000 ft./ min. is suitable for circular saws; band saw speed should be approximately 3,000 ft./min. Carbide-tipped blades are preferable when quantities of pipe are to be cut. To ensure square-ends, a miter box hold-down or jig should be used. Pipe or tubing cutters can be used for smaller diameter pipe when the cutting wheel is specifically designed for plastic pipe.

Threading Dies

Thread cutting dies should be clean, sharp and in good condition, and should not be used to cut materials other than plastics. Dies with a 5° negative front rake are recommended when using power threading equipment and dies with a 5° to 10° negative front rake are recommended when cutting threads by hand.

Threading and Joining

1. Hold pipe firmly in a pipe vise. Protect the pipe at the point of grip by inserting a rubber sheet or other material between the pipe and vise.



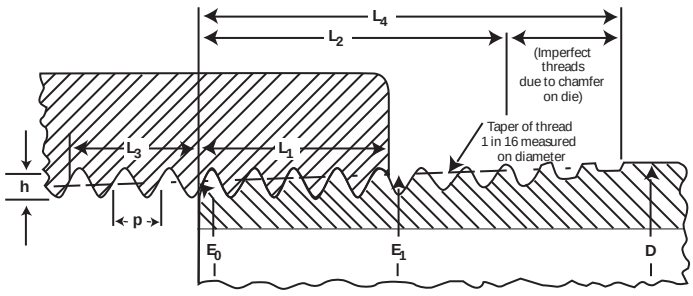
PIPE AND FITTING THREADS
AMERICAN STANDARD TAPER PIPE THREAD, NPT
(excerpt from ANSI B1.20.1)

(NOTE: Special dies for threading plastic pipe are available). When cutting threads with power threading equipment, self opening die heads and a slight chamfer to lead the dies will speed production.

Nominal Size	Outside Diameter D	Number of Threads Per Inch n	Pitch of Thread p	Normal Engagement By Hand L1	Normal Engagement By Hand L2	"Wrench Makeup Length For Internal Thread L3"	Total Length: End of Pipe to Vanish Point L4	Pitch Diameter at Beginning of External Thread E0	Pitch Diameter at Beginning of Internal Thread E1	Height of Thread (Max.) h
IN	IN	IN	IN	IN	IN	IN	IN	IN	IN	IN
1/4	0.54	18	.05556	.228	.4018	.1667	.5946	.47739	.49163	.04444
1/2	0.84	14	.07143	.32	.5337	.2143	.7815	.75843	.77843	.05714
3/4	1.05	14	.07143	.339	.5457	.2143	.7935	.96768	.98887	.05714
1	1.315	11 1/2	.08696	.400	.6828	.2609	.9845	1.21363	1.23863	.06957
1 1/4	1.660	11 1/2	.08696	.420	.7068	.2609	1.0085	1.55713	1.58338	.06957
1 1/2	1.900	11 1/2	.08696	.420	.7235	.2609	1.0252	1.79609	1.82234	.06957
2	2.375	11 1/2	.08696	.436	.7565	.2609	1.0582	2.26902	2.29627	.06957
2 1/2	2.875	8	.12500	.682	1.1375	.2500	1.5712	2.71953	2.76216	.10000
3	3.500	8	.12500	.766	1.2000	.2500	1.6337	3.34062	3.38850	.10000
4	4.500	8	.12500	.844	1.3000	.2500	1.7337	4.33438	4.38712	.10000

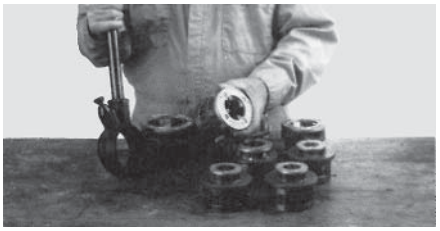
2. A tapered plug must be inserted in the end of the pipe to be threaded. This plus provides additional support and prevents distortion of the pipe in the threaded area. Distortion of the pipe during the threading operation will result in eccentric threads, non-uniform circumferential thread depth or gouging and tearing of the pipe wall. See the following Table for approximate plug O.D. dimensions.

DO NOT THREAD SCHEDULE 40 PIPE



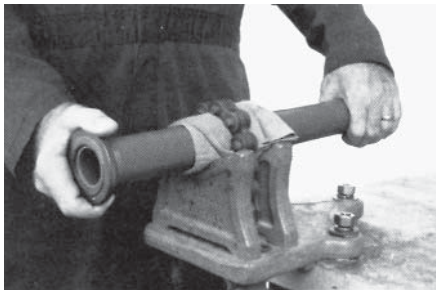
Reinforcing Plug Dimensions	
PIPE SIZE	PLUG O.D.*
1/2”	.526
3/4”	.722
1”	.935
1-1/4”	1.254
2”	1.913
2-1/2	2.289
3	2.864
4	3.786

*These dimensions are based on the median wall thickness and average outside diameter for the respective pipe sizes. Variations in wall thicknesses and O.D. dimensions may require alteration of the plug dimensions.

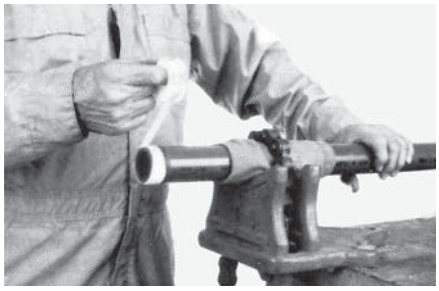


3. Use a die stock with a proper guide that is free of burrs or sharp edges, so the die will start and go on square to the pipe axis.

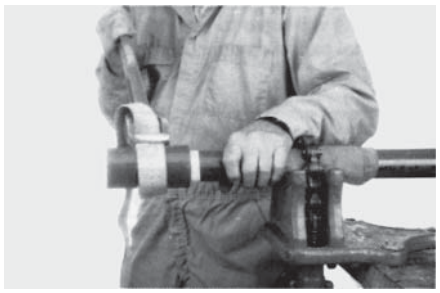
4. Push straight down on the handle, avoiding side pressure that might distort the sides of the threads. If power threading equipment is used, the dies should not be driven at high speeds or with heavy pressure. Apply an external lubricant liberally when cutting the threads. Advance the die to the point where the thread dimensions are equal to those listed in Table No. 1. Do not over thread.



5. Periodically check the threads with a ring gauge to ensure that proper procedures are being followed. Thread dimensions are listed in Table 1 and the gauging tolerance is ± 1-1/2 turns.



6. Brush threads clean of chips and ribbons. Then starting with the second full thread, and continuing over the thread length, wrap TFE (Teflon) thread tape in the direction of the threads. Overlap each wrap by one half of the width of the tape. FABCO does not recommend the use of any thread lubricant/sealant other than TFE (Teflon) tape.



7. Thread the fitting onto the pipe and tighten by hand. Using a strap wrench only, further tighten the connection an additional one or two threads past hand tightness. Avoid excessive torque as this may cause thread damage or fitting damage.

PRESSURE TESTING

Threaded piping systems can be pressure tested up to 100% of the hydrostatic pressure rating as soon as the last connection is made.

CAUTION: AIR OR COMPRESSED GAS IS NOT RECOMMENDED AND SHOULD NOT BE USED AS A MEDIA FOR PRESSURE TESTING OF PLASTIC PIPING SYSTEMS.

GENERAL UNDERGROUND INSTALLATION PROCEDURES FOR PVC AND CPVC SOLVENT WELDED PIPE

SCOPE

The general installation procedures detailed here apply to Polyvinyl Chloride (PVC) and Chlorinated Polyvinyl Chloride (CPVC) pressure pipe that has solvent welded joints up through 8" in size. These procedures are applicable for all liquids that are conveyed at pressures up to the maximum hydrostatic pressure rating of the pipe or of any component in the piping system, whichever is lowest.

Fabco Technical Services should be consulted for installation guidance and recommendation on all sizes of pipe 10" and above and where the installer has had no experience in the installation of PVC or CPVC piping. For additional information, refer to the ASTM D2774, "Underground Installation of Thermoplastic Pressure Piping".

INSPECTION

Before installation, all lengths of PVC or CPVC pipe and fittings should be thoroughly inspected for cuts, scratches, gouges, buckling, kinking and any other imperfections (such as splits on I.D. or ends of pipe due to impact) which may have been imparted to the pipe during shipping, unloading, storing and stringing. Any pipe or precoupled fittings containing harmful or even questionable defects should be removed by cutting out the damaged section as a complete cylinder.

TRENCHING

The trench should be of adequate width to allow convenient installation of PVC or CPVC pipe, at the same time being as narrow as possible. The following trench sizes have been used with success. However, actual sizes may vary with terrain and specific application.

Minimum trench widths may be utilized by joining pipe outside of the trench and lowering it into the trench after adequate joint strength has been obtained. Trench widths will have to be wider where pipe is joined in the trench, or where thermal expansion and contraction is a factor. See section title "Snaking of Pipe".

PIPE SIZE TRENCH	WIDTH	LIGHT TRAFFIC GROUND COVER MINIMUM	HEAVY TRAFFIC GROUND COVER MINIMUM
3" & Under	8"	12" - 8"	24" - 30"
4" & 6"	12"	18" - 24"	30" - 36"
8"	16"	24" - 30"	36" - 42"

The trench bottom should be continuous, relatively smooth and free of rocks. Where ledge rock, hardpan or boulders are encountered, it is advisable to pad the trench bottom using a minimum of four (4) inches of tamped earth or sand beneath the pipe as a cushion and for protection of the pipe from damage.

Sufficient cover must be maintained to keep external stress levels below acceptable design stress. Reliability and safety of service may assume major importance in determining minimum cover. Local, provincial and national codes may also govern.

Pipe intended for water service should be buried at least 12" below the maximum expected frost penetration.

SIZE OF JOINING CREW

Field practice has shown that the size of the joining crew will depend upon a number of variables, such as, size and length of the pipe, the atmospheric temperature, construction conditions, construction time element, amount of pipe to be layed, construction workers' experience in laying PVC or CPVC pipe, etc. Although it is possible for one man to join the smaller sizes of pipe (2" and under) by himself, it is not necessarily practical to do so. Therefore, the crew sizes presented here are intended as a guide for those PVC or CPVC pipe users who have not had a great deal of experience in the installation of such buried pipe:

1 MAN	Size Pipe 1-1/4" and under. Size Pipe 1-1/2" and 2" maximum 20' lengths.
2 MEN	1-1/2" and 2" where lengths are over 20' or atmospheric temperature is over 90°F. 2-1/2" and 3" pipe in maximum lengths of 20'.
3 MEN*	2-1/2" and 3" pipe where lengths are over 20' or atmospheric temperature is over 90°F. 4" through 8" size pipe.
4 MEN**	6" and 8" size pipe where atmospheric temperature is over 90°F.

* Two men do the priming and solvent welding while the third man is positioned at the end of the pipe in order to assist in pushing it into its fully bottomed position in the fitting socket.

**Two men do the priming and apply the cement to the pipe surface while a third man does the same to the fitting socket. The fourth man is positioned at the end of the pipe in order to assist in pushing it into its fully bottomed position in the fitting socket.

NOTE: The need for an extra man when the temperature is over 90°F, is necessary in order to quickly complete the solvent cement application and joining process before rapid evaporation of the cement's solvent causes it to prematurely set.

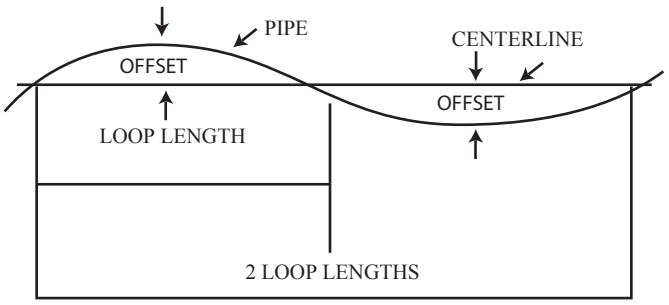
SOLVENT WELDING

For joining recommendations, see the section titled "Solvent Welding instructions for PVC and CPVC Pressure Pipe Systems"

SNAKING OF PIPE

After the PVC or CPVC pipe has been solvent welded, it is advisable to snake the pipe according to the below recommendations beside the trench during its required drying time. BE ESPECIALLY CAREFUL NOT TO APPLY ANY STRESS THAT WILL DISTURB THE UNDRIED JOINT. This snaking is necessary in order to allow for any anticipated thermal contraction that will take place in the newly joined pipeline.

PIPE SNAKING



Loop Offset In Inches For Contraction

Maximum Temperature Variation, °F, Between Time of Solvent Welding and Final Use

PIPE SIZE TRENCH	WIDTH	LIGHT TRAFFIC GROUND COVER MINIMUM	HEAVY TRAFFIC GROUND COVER MINIMUM
3" & Under	8"	12" - 8"	24" - 30"
4" & 6"	12"	18" - 24"	30" - 36"
8"	16"	24" - 30"	36" - 42"

Snaking is particularly necessary on the lengths that have been solvent welded during the late afternoon of a hot summer's day, because their drying time will extend through the cool of the night when thermal contraction of the pipe could stress the joints to the

point of pull out. This snaking is also especially necessary with pipe that is layed in its trench (necessitating wider trenches than recommended) and if back-filled with cool earth before the joints are thoroughly dry.

BENDING OF PLASTIC PIPE

Whenever a change of direction is required in a pipeline, it is best accomplished using straight lengths of pipe and factory-made fittings. Bending of pipe leaves residual stresses and consequently bending is not recommended as a normal practice, particularly if the line is intended to operate at or near maximum temperatures and/or pressure.

If field bending is required to meet special conditions the following techniques should be employed to give the best results.

1. Heating Media: The heating media may be hot air in a circulating oven operating at approximately 360° F. The heating media may also be radiant heat in which case the pipe must be rotated to ensure uniform heating over the entire pipe surface in the area of the bend or the pipe may be immersed in hot oil. An open flame should never be used. Heating times will range from approximately one to five minutes or until it becomes soft and pliable enough to bend, depending upon pipe size and type of heat source.

2. To maintain the cross sectional area of the I.D. of the pipe in the area of the bend it must be supported during the bending operations. There are three suggested methods for supporting the pipe.

   a. The I.D. can be supported by filling with preheated sand and plugging both ends.

   b. A heated reinforcing spring can be placed inside the pipe after it has been heated to a soft, pliable condition. The spring should be made with 3/32" diameter wire and the O.D. of the spring should be slightly less than the nominal I.D. of the pipe to be bent. Springs can be custom made by any local spring manufacturer.

   c. When the pipe becomes soft and pliable it can be placed in a forming jig or form and bent as quickly as possible to prevent weakening or deforming of the pipe.

3. The minimum radius to which a bend should be made, measured from the inner edge of the curve, should be 8 pipe diameters for 3/4" pipe size and below and 6 pipe diameters for larger pipe. The initial forming bend will have to be slightly greater to allow for spring back.

4. The bend should be kept in the bent form until the pipe cools and becomes rigid enough to be handled without deforming. It should then be immediately immersed in water to complete the cooling process. The sand or spring should not be removed until final cooling is completed. When plastic pipe is heated and then bent, it will shrink with the degree of shrinkage depending on the size of the pipe and the radius of the bend. Therefore, the pipe should be cut to lengths slightly greater than the total length of the bend and the tangents.

5. A straight section of at least two pipe diameters should be left at either side of the bend to insure a round, low stress section with which to make joints.

6. Highly crystalline thermoplastics such as PVDF should never be formed in this way due to the potential detrimental effect of the process on the molecular structure and properties of the material.

The above discussion covers only the basics involved with bending plastic pipe. Experience and some trial-and-error will be required to develop an expertise in bending pipe. Contact FABCO with further questions.

CLEANING

Even though care should be exercised at all times to prevent the entry of dirt, water and other foreign material into the PVC or CPVC pipe and fittings, it is advisable that the pipeline be thoroughly cleaned before working pressure is applied.

TESTING

See section titled "Solvent Welding Instructions for PVC and CPVC Pressure Pipe Systems."

BACKFILLING

Ideally, backfilling should only be done early in the morning during hot weather when the line is fully contracted and there is no chance of insufficiently dried joints being subject to contraction stresses.

The pipe should be uniformly and continuously supported over its entire length on firm, stable material. Blocking should not be used to change pipe grade or to intermittently support pipe across excavated sections.

Pipe is installed in a wide range of sub-soils. These soils should not only be stable but applied in such a manner so as to physically shield the pipe from damage. Attention should be given to local pipe laying experience which may indicate particular pipe bedding problems.

Backfill materials free of rocks with a particle size of 1/2" or less should be used to surround the pipe with 6" to 8" of cover. It should be placed in layers. Each soil layer should be sufficiently compacted to uniformly develop lateral passive soil forces during the backfill operation. It may be advisable to have the pipe under pressure, 15 to 25 psi during the backfilling.

Effects of ground freezing should be considered when pipe is installed at depths subject to frost penetration.

Vibratory methods are preferred when compacting sand or gravels. Best results are obtained when the soils are in a nearly saturated

condition. Where water flooding is used, the initial backfill should be sufficient to insure complete coverage of the pipe. Additional material should not be added until the water flooded backfill is firm enough to walk on. Care should be taken to avoid floating the pipe.

Sand and gravel containing a significant proportion of fine-grained material, such as silt and clay, should be compacted by hand or, preferably by mechanical tamper.

The remainder of the backfill should be placed and spread in approximately uniform layers in such a manner to fill the trench completely so that there will be no unfilled spaces under or about rocks or lumps of earth in the backfill. Large or sharp rocks, frozen clods and other debris greater than 3" in diameter should be removed. Rolling equipment or heavy tampers should only be used to consolidate the final backfill.

Additional information on underground installation is given in ASTM D2321 "Underground Installation of Flexible Thermoplastic Sewer Pipe" and ASTM D2774 "Underground Installation of Thermoplastic Pressure Piping."

CONNECTING PIPE SECTIONS
Sections of PVC or CPVC pipe that have been backfilled or plowed in during the heat of the day should be sufficiently overlapped to allow for contraction and not joined up to one another or any stable connection or fitting until the morning following their night of cooling and thermal contraction. See the section "Expansion and Contraction of Plastic Pipe" for calculating anticipated contraction.

PIPE LOCATING
The location of all PVC and CPVC pipelines should be accurately and precisely recorded. Conductive wire can be trenched or plowed in with the pipe as an aid for future locating purposes.

BELOW GRADE VALVES, ANCHORS OR OTHER CONNECTIONS
As a rule of thumb in designing and installing a PVC or CPVC underground piping system, it is pointed out that pipe made from these materials is not designed to be used for any structural applications beyond withstanding normal soil loads and internal pressures up to its hydrostatic pressure rating.

Anchors, valve boxes, etc. must be independently supported so as to not introduce additional bending or sheer stress on the pipe.

ROADWAYS AND RAILROAD TRACKS
It is recommended that plastic pipe be run within a metal or concrete casing when it is installed beneath surfaces that are subject to heavyweight or constant traffic; such as roadways, railroad tracks, etc.

CONCRETE ANCHORS
Concrete anchors can be poured around PVC or CPVC pipe at direction changes. If the purpose for anchoring is to restrain axial movement of the pipe, this can be done by solvent welding split collars around the pipe O.D. to provide a shoulder against the concrete wall. Solvent welding surface between collar and pipe O.D. must dry 48 hours prior to pouring of concrete.

RISERS
Although PVC or CPVC pipe has excellent weathering resistance, it should never be brought above grade under the following circumstances:

1. If it is expected to provide structural strength, such as supporting an above-grade metal valve. The metal valve should be installed with an independent support.

2. If it is subject to external damage. This could be remedied by sleeving the pipe with an independently and rigidly supported steel pipe.

3. If it is subject to high temperature environments; i.e., summer sun that could lower the pipe's pressure rating below an acceptable level. Such a situation might be remedied by insulating the PVC or CPVC pipe.

Engineering Data

Pressure Ratings of Fabco Products

The pressure carrying capability of any pipe at a given temperature is a function of the material strength from which the pipe is made and the geometry of the pipe as defined by its diameter and wall thickness. The following expression, commonly known as the ISO equation, is used in thermoplastic pipe specifications to relate these factors:

$$P = 2S / (Do/t - 1)$$

where: P = maximum pressure rating, psi
S = maximum hydraulic design stress (max. working strength), psi
Do = average outside pipe diameter, in.
t = minimum wall thickness, in.

The allowable design stress, which is the tensile stress in the hoop direction of the pipe, is derived for each material in accordance with ASTM D 2837, Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials, at 73° F. The pressure ratings below were calculated from the basic Hydraulic Design Stress for each of the materials.

Pipe and Fittings

In order to determine the pressure rating for a product system, first find the plastic material and schedule of pipe and fittings in the heading of the Maximum Non-Shock Operating Pressure table below. Then, locate the selected joining method in the subheading of the table and go down the column to the value across from a particular pipe size, listed in the far left column. This will be the maximum non-shock operating pressure at 73° F for the defined product system.

Maximum Non-Shock Operating Pressure (psi) at 73° F[1]

	Schedule 40 PVC & CPVC	Schedule 80 PVC & CPVC		Schedule 80 Polypropylene		Schedule 80 PVDF	
Nom. Pipe Size	Socket End	Socket End	Threaded End	Thermo Seal Joint	Threaded	Thermo Seal Joint	Threaded
1/2	600	850	420	410	20	580	290
3/4	480	690	340	330	20	470	230
1	450	630	320	310	20	430	210
1 1/4	370	520	260	260	20	—	—
1 1/2	330	470	240	230	20	326	160
2	280	400	200	200	20	270	140
2 1/2	300	420	210	—	—	—	—
3	260	370	190	190	20	250	N.R.
4	220	320	160	160	20	220	N.R
6	180	280	N.R.	140	N.R.	190	N.R.
8	160	2502	N.R.	—	—	—	—
10	140	230	N.R.	—	—	—	—
12	130	230	N.R.	—	—	—	—

1. For more severe service, an additional correction factor may be required.
2. 8" CPVC Tee, 90° ELL and 45° ELL rated at 1/2 of value shown. Pressure rating of 175 psi can be obtained by factory overwrapping with glass and polyester. Consult Customer Service for delivery information.
3. Recommended for intermittent drainage pressure not exceeding 20 psi.

N.R. Not Recommended.

Valves, Unions, and Flanges

The maximum pressure rating for valves, flanges, and unions, regardless of size, is 150 psi at 73° F. As with all other thermoplastic piping components, the maximum non-shock operating pressure is related to temperature. Above 100° F refer to the chart below.

Maximum Non-Shock Operating Pressure (psi) vs. Temperature

Temperature (° F)	PVC	CPVC	PP	PVDF
100	150	150	150	150
110	135	140	140	150
120	110	130	130	150
130	75	120	118	150
140	50	110	105	150
150	N.R.	100	93	140
160	N.R.	90	80	133
170	N.R.	80	70	125
180	N.R.	70	50	115
190	N.R.	60	N.R.	106
200	N.R.	50	N.R.	97
250	N.R.	N.R.	N.R.	50
280	N.R.	N.R.	N.R.	25

N.R. Not Recommended.

Temperature Ratings of Fabco Products

Since the strength of plastic pipe is sensitive to temperature, the identical test method is used to determine the material strength at elevated temperature levels. The correction factor for each temperature is the ratio of strength at that temperature level to the basic strength at 73° F. Because the hoop stress is directly proportional to the internal pressure, which created that pipe stress, the correction factors may be used for the temperature correction of pressure as well as stress. For pipe and fitting applications above 73° F, refer to the table below for the Temperature Correction Factors. To determine the maximum non-shock pressure rating at an elevated temperature, simply multiply the base pressure rating obtained from the table in the preceding column by the correction factor from the table below. The allowable pressure will be the same as the base pressure for all temperatures below 73° F.

Engineering Data

Temperature Correction Factors

Operating Temperature (° F)	Factors			
	PVC	CPVC	PP	PVDF
70	1.00	1.00	1.00	1.00
80	0.90	0.96	0.97	0.95
90	0.75	0.92	0.91	0.87
100	0.62	0.85	0.85	0.80
110	0.50	0.77	0.80	0.75
115	0.45	0.74	0.77	0.71
120	0.40	0.70	0.75	0.68
125	0.35	0.66	0.71	0.66
130	0.30	0.62	0.68	0.62
140	0.22	0.55	0.65	0.58
150	N.R.	0.47	0.57	0.52
160	N.R.	0.40	0.50	0.49
170	N.R.	0.32	0.26	0.45
180	N.R.	0.25	*	0.42
200	N.R.	0.18	N.R.	0.36
210	N.R.	0.15	N.R.	0.33
240	N.R.	N.R.	N.R.	0.25
280	N.R.	N.R.	N.R.	0.18

* Recommended for intermittent drainage pressure not exceeding 20 psi.
N.R. Not Recommended.

Pressure Rating of Fabco Products

Fabco Products in Vacuum or Collapse Loading Situations
Thermoplastic pipe is often used in applications where the pressure on the outside of the pipe exceeds the pressure inside. Suction or vacuum lines and buried pipe are examples of this type of service. As a matter of practical application, gauges indicate the pressure differential above or below atmospheric pressureHowever, scientists and engineers frequently express pressure on an absolute scale where zero equals a theoretically perfect vacuum and standard atmospheric pressure equals 14.6959 psia.

Solvent cemented or thermo-sealed joints are particularly recommended for vacuum service. In PVC, CPVC, PP, or PVDF vacuum systems, mechanical devices such as valves and transition joints at equipment will generally represent a greater intrusion problem than the thermoplastic piping system will. Experience indicates that PVC vacuum systems can be evacuated to pressures as low as 5 microns with continuous pumping. However, when the system is shut off, the pressure will rise and stabilize around 10,000 microns or approximately 10 mm of Mercury at 73° F. The following chart lists the allowable collapse loading for plastic pipe at 73° F. It shows how much greater the external pressure may be than the internal pressure. (Thus, a pipe with 100 psi internal pressure can withstand 100 psi more external pressure than a pipe with zero psi internal pressure.) For temperatures other than 73° F, multiply the values in the chart by the correction factors listed in the temperature correction table on the preceding page. The chart also applies to a vacuum. The external pressure is generally atmospheric pressure, or 0.0 psig, while the internal pressure is normally identified as a vacuum or negative gauge pressure. However, this negative value will never exceed –14.7 psig. Therefore, if the allowable pressure listed in the chart (after temperature correction) is greater than the difference for internal-to-external pressure, the plastic system is viable.

Pipe Size	Sch. 40 PVC	Sch. 80 PVC	Sch. 80 CPVC	Sch. 80 PP	Sch. 80 PVDF
1/2	450	575	575	230	391
3/4	285	499	499	200	339
1	245	469	469	188	319
1 1/4	160	340	340	136	—
1 1/2	120	270	270	108	183
2	75	190	190	76	129
2 1/2	100	220	220	—	—
3	70	155	155	62	105
4	45	115	115	46	78
6	25	80	80	32	54
8	16	50	50	—	—
10	12	43	—	—	—
12	9	39	—	—	—

Pressure Losses in a Piping System

Piping Calculations

As a fluid flows through a piping system, it will experience a head-loss depending on, among other factors, fluid velocity, pipe wall smoothness and internal pipe surface area. The Tables on pages 9 and 10 give Friction Loss and Velocity data for Schedule 40 and Schedule 80 thermoplastic pipe based on the Williams and Hazen formula.

$$H=0.2083 \times (100/C)^{1.852} \times (q^{1.852}/d^{4.8655})$$

Where: H = Friction Head Loss in Feet of Water/100 Feet of Pipe
C = Surface Roughness Constant (150 for all thermoplastic pipe)
q = Fluid Flow (gallons/min.)
d = Inside Diameter of Pipe

Fittings and valves, due to their more complex configurations, contribute significant friction losses in a piping system. A common method of expressing the losses experienced in fittings is to relate them to pipe in terms of equivalent pipe length. This is the length of pipe required to give the same friction loss as a fitting of the same size. Tables are available for the tabulation of the equivalent

Engineering Data

pipe length in feet for the various sizes of a number of common fittings. By using this Table and the Friction Loss Tables, the total friction loss in a plastic piping system can be calculated for any fluid velocity.

For example, suppose we wanted to determine the pressure loss across a 2" Schedule 40, 90° elbow, at 75 gpm. From the lower table we find the equivalent length of a 2" 90° elbow to be 5.5 feet of pipe. From the Schedule 40 Pipe Table we find the friction loss to be 3.87 psi per 100 feet of pipe when the flow rate is 75 gpm. Therefore, the solution is as follows:

5.5 Feet/90° Elbow x 3.87 psi/100 Feet = 0.21 psi Pressure Drop/90° Elbow

which is the pressure drop across a 2" Schedule 40 elbow. But, what if it were a 2" Schedule 80 elbow, and we wanted to know the friction head loss? The solution is similar, except we look for the friction head in the Schedule 80 Pipe Table and find it to be 12.43 feet per 100 feet of pipe when the flow rate is 75 gpm. The solution follows:

5.5 Feet/90° Elbow x 12.43 Feet/100 Feet = 0.68 Feet Friction Head/90° Elbow

which is the friction head loss across a 2" Schedule 80 elbow. For a copy of the tables mentioned in this section, please contact customer service.

Valve Calculations

As an aid to system design, liquid sizing constants (Cv values) are shown for valves where applicable. These values are defined as the flow rate through the valve required to produce a pressure drop of 1 psi. To determine the pressure drop for a given condition the following formula may be used:

$$P=(Q^2 S.G.)/(C_V^2)$$

Where:
P = Pressure drop across the valve in psi
Q = Flow through the valve in gpm
S.G. = Specific gravity of the liquid (Water = 1.0)
Cv = Flow coefficient
See the solution of the following example problem. For Cv values for specific valves, contact customer service or consult the manufacturers catalog.

EXAMPLE:
Find the pressure drop across a 1 1/2" PVC ball check valve with a water flow rate of 50 gpm. The Cv is 56.

$$P=(50^2 \times 1.0)/56^2$$
$$P=(50/56)^2$$
$$P=0.797 \text{ psi}$$

Hydraulic Shock

Hydraulic shock is the term used to describe the momentary pressure rise in a piping system which results when the liquid is started or stopped quickly. This pressure rise is caused by the momentum of the fluid; therefore, the pressure rise increases with the velocity of the liquid, the length of the system from the fluid source, or with an increase in the speed with which it is started or stopped. Examples of situations where hydraulic shock can occur are valves which are opened or closed quickly or pumps which start with an empty discharge line. Hydraulic shock can even occur if a high-speed wall of liquid (as from a starting pump) hits a sudden change of direction in the piping, such as an elbow.

The pressure rise created by the hydraulic shock effect is added to whatever fluid pressure exists in the piping system and, although only momentary, this shock load can be enough to burst pipe and break fittings or valves.

Proper design when laying out a piping system will limit the possibility of hydraulic shock damage.

The following suggestions will help in avoiding problems:

1. In a plastic piping system, a fluid velocity not exceeding 5 ft./sec. will minimize hydraulic shock effects, even with quickly closing valves, such as solenoid valves. (Flow is normally expressed in GALLONS PER MINUTE—GPM. To determine the fluid velocity in any segment of piping the following formula may be used:

   $$V=(0.4085 \times GPM)/D_i^2$$

   Where:
   v = fluid velocity in feet per second
   D_i = inside diameter
   GPM = rate of flow in gallons per minute

   Flow Capacity Tables are available for the fluid velocities resulting from specific flow rates in Schedule 40 and Schedule 80 pipes. The upper threshold rate of flow for any pipe may be determined by substituting 5 ft./sec. Fluid velocity in the above formula and solving for GPM. Upper Threshold Rate of Flow (GPM) = 12.24 Di2

2. Using actuated valves, which have a specific closing time, will eliminate the possibility of someone inadvertently slamming a valve open or closed too quickly. With air-to-air and air-to-spring actuators, it will probably be necessary to place a flow control valve in the air line to slow down the valve operation cycle, particularly on valve sizes greater than 1 1/2".
3. If possible, when starting a pump, partially close the valve in the discharge line to minimize the volume of liquid that is rapidly accelerating through the system. Once the pump is up to speed and the line completely full, the valve may be opened.

Engineering Data

4. A check valve installed near a pump in the discharge line will keep the line full and help prevent excessive hydraulic shock during pump start-up. Before initial start-up the discharge line should be vented of all air. Air trapped in the piping will substantially reduce the capability of plastic pipe withstanding shock loading.

Shock Surge Wave
Providing all air is removed from an affected system, a formula based on theory may closely predict hydraulic shock effect.
Where:
p = maximum surge pressure, psi
v = fluid velocity in feet per second.
C = surge wave constant for water at 73° F.
*SG = specific gravity of liquid, *if SG is 1, then p = vC

EXAMPLE:
A 2" PVC Schedule 80 pipe carries a fluid with a specific gravity of 1.2 at a rate of 30 gpm and at a line pressure of 160 psi. What would the surge pressure be if a valve were suddenly closed?
From table below:
c = 24.2 v = 3.35
p = (3.35) (26.6) = 90 psi

Total line pressure = 90 + 160 = 250 psi

Schedule 80 2" PVC has a pressure rating of 400 psi at room temperature. Therefore, 2" Schedule 80 PVC pipe is acceptable for this application.

Surge Wave Constant(C)

Pipe	PVC		CPVC		PP	PVDF
	Sch. 40	Sch. 80	Sch. 40	Sch. 80	Sch. 80	Sch. 80
1/4	31.3	34.7	33.2	37.3	—	—
3/8	29.3	32.7	31.0	34.7	—	—
1/2	28.7	31.7	30.3	33.7	25.9	28.3
3/4	26.3	29.8	27.8	31.6	23.1	25.2
1	25.7	29.2	27.0	30.7	21.7	24.0
1 1/4	23.2	27.0	24.5	28.6	19.8	—
1 1/2	22.0	25.8	23.2	27.3	18.8	20.6
2	20.2	24.2	21.3	25.3	17.3	19.0
2 1/2	21.1	24.7	22.2	26.0	—	—
3	19.5	23.2	20.6	24.5	16.6	18.3
4	17.8	21.8	18.8	22.9	15.4	17.0
6	15.7	20.2	16.8	21.3	14.2	15.8
8	14.8	18.8	15.8	19.8		
10	14.0	18.3	15.1	19.3		
12	13.7	18.0	14.7	19.2		
14	13.4	17.9	14.4	19.2		

CAUTION: The removal of all air from the system in order for the surge wave analysis method to be valid was pointed out at the beginning of this segment. However, this can be easier said than done. Over reliance on this method of analysis is not encouraged. Our experience suggests that the best approach to assure a successful installation is for the design to focus on strategic placements of air vents and the maintenance of fluid velocity near or below the threshold limit of 5 ft./sec.

Expansion and Thermal Contraction of Plastic Pipe

Calculating Dimensional Change
All materials undergo dimensional change as a result of temperature variation above or below the installation temperature. The extent of expansion or contraction is dependent upon the coefficient of linear expansion for the piping material. These coefficients are listed below for the essential industrial plastic piping materials in the more conventional form of inches of dimensional change, per ° F of temperature change, per inch of length. They are also presented in a more convenient form to use. Namely, the units are inches of dimensional change, per 10° F temperature change, per 100 feet of pipe.

Expansion Coefficient

Material	C(in/in/° Fx10^{-5})	Y(in/10° F/100 ft.)
PVC	3.0	.360
CPVC	3.8	.456
PP	5.0	.600
PVDF	7.9	.948

The formula for calculating thermally induced dimensional change, utilizing the convenient coefficient (Y), is dependent upon the temperature change to which the system may be exposed – between the installation temperature and the greater differential to maximum or minimum temperature – as well as, the length of pipe run between directional changes or anchors points. Also, a handy chart is presented at the bottom of this column, which approximates the dimensional change based on temperature change vs. pipe length.

$L=Yx(T_1-T_2)/10$ X L/100
L = Dimensional change due to thermal expansion or contraction(in)
Y = Expansion coefficient (See table above) (in/10°/100 ft)
(T_1-T_2) = Temperature differential between the installation temperature and the maximum or minimum system temperature, whichever provides the greatest differential (° F).
L = Length of pipe run between changes in direction (ft.)

Engineering Data

EXAMPLE 1:
How much expansion can be expected in a 200 foot straight run of 3 inch PVC pipe that will be installed at 75° F when the piping system will be operated at a maximum of 120° F and a minimum of 40° F?

L=(120-75)/10 X 200/100 = 0.360 X 4.50 X 2.0=3.24 inches

Temp	Length of Pipe to Closest Anchor Point (ft.)									
T(° F)	10'	20'	30'	40'	50'	60'	70'	80'	90'	100'
10°	0.04	0.07	0.11	0.14	0.18	0.22	0.25	0.29	0.32	0.36
20°	0.07	0.14	0.22	0.29	0.36	0.43	0.50	0.58	0.65	0.72
30°	0.11	0.22	0.32	0.43	0.54	0.65	0.76	0.86	0.97	1.08
40°	0.14	0.29	0.43	0.58	0.72	0.86	1.00	1.15	1.30	1.44
50°	0.18	0.36	0.54	0.72	0.90	1.08	1.26	1.44	1.62	1.80
60°	0.22	0.43	0.65	0.86	1.08	1.30	1.51	1.73	1.94	2.16
70°	0.25	0.50	0.76	1.01	1.26	1.51	1.76	2.02	2.27	2.52
80°	0.29	0.58	0.86	1.15	1.44	1.73	2.02	2.30	2.59	2.88
90°	0.32	0.65	0.97	1.30	1.62	1.94	2.27	2.59	2.92	3.24
100°	0.36	0.72	1.08	1.44	1.80	2.16	2.52	2.88	3.24	3.60
110°	0.40	0.79	1.19	1.58	1.98	2.38	2.77	3.17	3.56	3.96
120°	0.43	0.86	1.30	1.73	2.16	2.59	3.02	3.46	3.89	4.32

* Temperature change (T) from installation to the greater of maximum or minimum limits.

To determine the expansion or contraction for pipe of a material other than PVC, multiply the change in length given for PVC in the table above by 1.2667 for the change in CPVC, by 1.6667 for the change in PP, or by 2.6333 for the change in PVDF.

Calculating Stress
If movement resulting from thermal changes is restricted by the piping support system or the equipment to which it is attached, the resultant forces may damage the attached equipment or the pipe itself. Therefore, pipes should always be anchored independently at those attachments. If the piping system is rigidly held or restricted at both ends when no compensation has been made for thermally induced growth or shrinkage of the pipe, the resultant stress can be calculated with the following formula.
$S_t = EC (T_1-T_2)$
S_t = Stress (psi)
E = Modulus of Elasticity (psi) (See table below for specific values at various temperatures)
C = Coefficient of Expansion (in/in/ ° F x 105)
(see physical property chart on page 2 for values)
(T_1-T_2) = Temperature change (° F) between the installation temperature and the maximum or minimum system temperature, whichever provides the greatest differential.

Modulus of Elasticity

	73° F	90° F	100° F	140° F	180° F	210° F	250° F
PVC	4.20	3.75	3.60	2.70	N/A	N/A	N/A
CPVC	4.23	4.00	3.85	3.25	2.69	2.20	N/A
PP	1.79	1.25	1.15	.72	.50	N/A	N/A
PVDF	2.19	1.88	1.74	1.32	1.12	.81	.59

N/A - Not Applicable

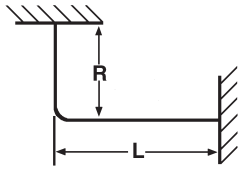
The magnitude of the resulting longitudinal force can be determined by multiplying the thermally induced stress by the cross sectional area of the plastic pipe.
$F = S_t \times A$
F = FORCE (lbs)
S_t = STRESS (psi)
A = CROSS SECTIONAL AREA (in^2)

EXAMPLE 2:
What would be the amount of force developed in 2" Schedule 80 PVC pipe with the pipe rigidly held and restricted at both ends? Assume the temperature extremes are from 70° F to 100° F.
$S_t = EC (T_1 - T_2)$
$S_t = EC (100 - 70)$
$S_t = (3.60 \times 105) \times (3.0 \times 10\text{-}5) (30)$
$S_t = 324$ psi
The Outside and Inside Diameters of the pipe are used for calculating the Cross Sectional Area (A) as follows: (See the Pipe Reference Table for the pipe diameters and cross sectional area for specific sizes of schedule 80 Pipes.)

$A = \pi/4 (OD^2 - ID^2) = 3.1416/4 (2.375^2 - 1.913^2) = 1.556\ in.^2$
The force exerted by the 2" pipe, which has been restrained, is simply the compressive stress multiplied over the cross sectional area of that pipe.
$F = S_t \times A$
$F = 324$ psi $\times 1.556\ in.^2$
F = 504 lbs.

Managing Expansion/Contraction in System Design

Stresses and forces which result from thermal expansion and contraction can be reduced or eliminated by providing for flexibility in the piping system through frequent changes in direction or introduction of loops as graphically depicted on this page.



Engineering Data

Normally, piping systems are designed with sufficient directional changes, which provide inherent flexibility, to compensate for expansion and contraction. To determine if adequate flexibility exists in leg (R) (see Fig. 1) to accommodate the expected expansion and contraction in the adjacent leg(L) use the following formula:

R = 2.877√D L SINGLE OFFSET FORMULA

Where: R = Length of opposite leg to be flexed (ft.)
D = Actual outside diameter of pipe (in.)
L = Dimensional change in adjacent leg due to thermal expansion or contraction (in.)

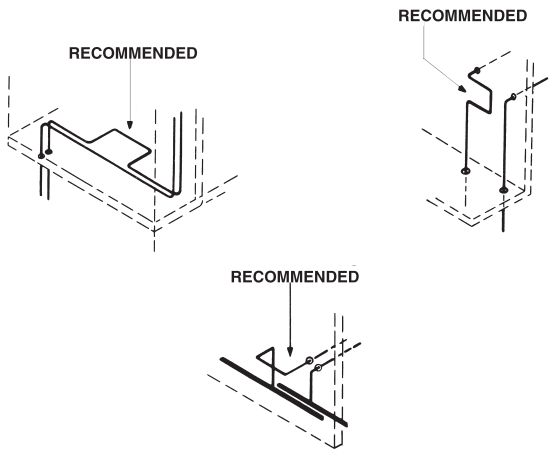
Keep in mind the fact that both pipe legs will expand and contract. Therefore, the shortest leg must be selected for the adequacy test when analyzing inherent flexibility in naturally occurring offsets.

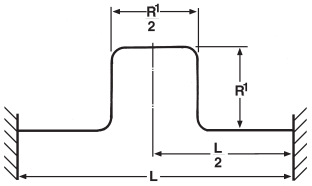
EXAMPLE 3:
What would the minimum length of a right angle leg need to be in order to compensate for the expansion if it were located at the unanchored end of the 200 ft. run of pipe in Example 1 from the previous page?

R = 2.877√3.500 x 3.24 = 9.69 ft.
Flexibility must be designed into a piping system, through the introduction of flexural offsets, in the following situations:

1. Where straight runs of pipe are long.
2. Where the ends of a straight run are restricted from movement.
3. Where the system is restrained at branches and/or turns.

Several examples of methods for providing flexibility in these situations are graphically presented below. In each case, rigid supports or restraints should not be placed on a flexible leg of an expansion loop, offset or bend.





An expansion loop (which is fabricated with 90° elbows and straight pipe as depicted in Fig. 2) is simply a double offset designed into an otherwise straight run of pipe. The length for each of the two loop legs (R'), required to accommodate the expected expansion and contraction in the pipe run (L), may be determined by modification of the SINGLE OFFSET FORMULA to produce a LOOP FORMULA, as shown below:

R' = 2.041√ D L LOOP FORMULA

EXAMPLE 4:

How long should the expansion loop legs be in order to compensate for the expansion in Example 1 from the previous page?

R' = 2.041√ 3.500 x 3.24 = 6.87 ft.

Minimum Cold Bending Radius
The formulae above for Single Offset and Loop bends of pipe, which are designed to accommodate expansion or contraction in the pipe, are derived from the fundamental equation for a cantilevered beam – in this case a pipe fixed at one end. A formula can be derived from the same equation for calculating the minimum cold bending radius for any thermoplastic pipe diameter.

Minimum Cold Bend Radius

$R_B = D_O (0.6999\ E/S_B - 0.5)$
Where: R_B = Minimum Cold Bend Radius (in.)
DO = Outside Pipe Diameter (in.)
E * = Modulus of Elasticity @ Maximum Operating Temperature (psi)
S_B * = Maximum Allowable Bending Stress @ Maximum Operating Temperature (psi)

*The three formulae on this page provide for the maximum bend in pipe while the pipe operates at maximum long-term internal pressure, creating maximum allowable hydrostatic design stress (tensile stress in the hoop direction). Accordingly, the maximum allowable bending stress will be one half the basic hydraulic design stress at 73° F with correction to the maximum operating temperature. The modulus of elasticity, corrected for temperature may be found in the table in the second column of the preceding page.

Engineering Data

EXAMPLE 5:
What would be the minimum cold radius bend, which the installer could place at the anchored end of the 200 ft. straight run of pipe in Examples 1 and 3, when the maximum operating temperature is 100° F instead of 140°F?

RB = 3.500 (0.6999 x 360,000/ 1/2 x 2000 x 0.62 – 0.5) =1,420.8 in. or 118.4 ft

PIPE SUPPORT SPACING

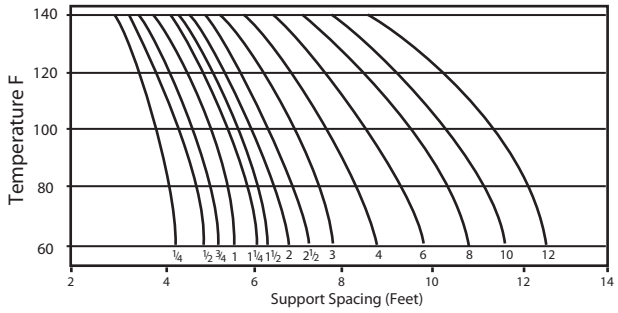
Correct supporting of a piping system is essential to prevent excessive bending stress and to limit pipe "sag" to an acceptable amount. Horizontal pipe should be supported on uniform centers, which are determined for pipe size, schedule, temperature, loading and material.

Point support must not be used for thermoplastic piping and, in general, the wider the bearing surface of the support the better. Supports should not be clamped in such a way that will restrain the axial movement of pipe that will normally occur due to thermal expansion and contraction. Concentrated loads in a piping system, such as valves must be separately supported.

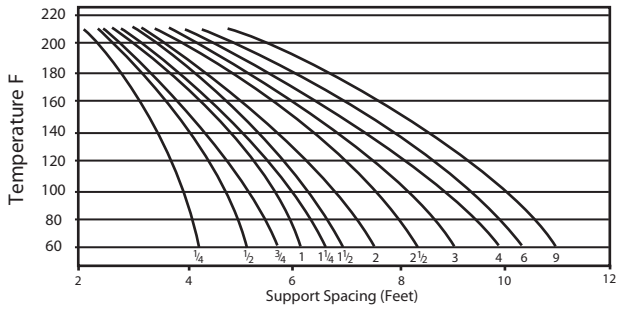
The graphs on this page give recommended support spacing for Chemtrol thermoplastic piping materials at various temperatures. The data is based on fluids with a specific gravity of 1.0 and permits a sag of less than 0.1" between supports. For heavier fluids, the support spacing from the graphs should be multiplied by the correct factor in the table below.

Specific Gravity	1.0	1.1	1.2	1.4	1.6	2.0	2.5
Correction Factor	1.0	.98	.96	.93	.90	.85	.80

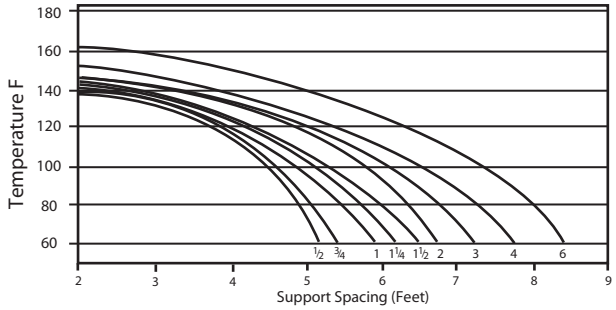
PVC Schedule 80



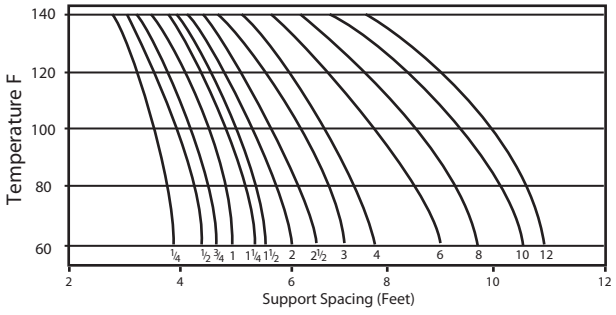
CPVC Schedule 80



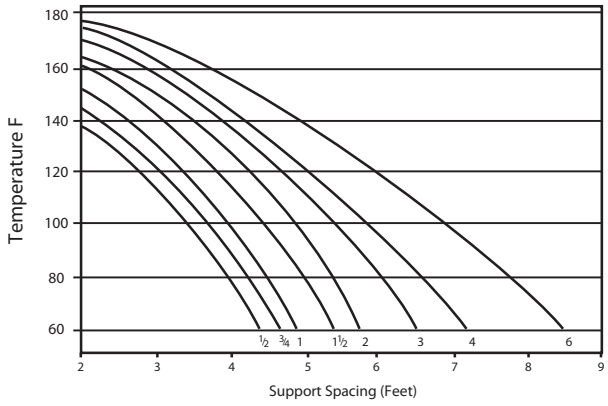
Polypropylene Schedule 80



PVC Schedule 40



PVDF Schedule 80



The above data is for uninsulated lines. For insulated lines, reduce spans to 70% of graph values. For spans of less than 2 feet, continuous support should be used.

PLASTIC PIPING STANDARDS

Many commercial, industrial and governmental standards or specifications are available to assist the design engineer in specifying plastic piping systems. Standards most frequently referred to and most commonly called out in plastic piping specifications are ASTM Standards. These standards also often form the basis of other standards in existence. Below is a list and description of those standards most typically applied to industrial plastic piping.

ASTM Standard D-1784
(American Society for Testing and Materials)
This standard covers PVC and CPVC compounds used in the manufacture of plastic pipe, valves, and fittings. It provides a means for selecting and identifying compounds on the bases of a number of physical and chemical criteria. Conformance to a particular material classification in this standard requires meeting a number of minimum physical and chemical properties.

ASTM Standards D-1785 and F-441
These standards cover the specification and quality of Schedule 40, 80 and 120 PVC (D-1785) and CPVC (F-441) pressure pipe. Outlined in these standards are dimensional specifications, burst, sustained and maximum operating pressure requirements and test procedures for determining pipe quality with respect to workmanship and materials.

ASTM Standards D-2464 and F-437
These standards cover PVC (D-2464) and CPVC (F-437) Schedule 80 threaded pressure fittings. Thread dimensional specifications, wall thickness, burst, material quality, and identification requirements are specified.

ASTM Standard D-2466
These standards cover Schedule 40 PVC (D-2466) threaded and socket pressure fittings. Stipulated in the standard are thread and socket specifications, by lengths, wall thickness, burst material, quality and identification requirements.

ASTM Standards D-2467 and F-439
Standards D-2467 (PVC) and F-439 (CPVC) cover the specification of Schedule 80 socket type pressure fittings, including dimensions and physical requirements.

ASTM Standard D-4101 (Formerly D-2146)
This standard covers the specifications for propylene (PP) plastic injection and extrusion materials.

ASTM Standard D-3222
This standard covers the specifications for PVDF fluoroplastic molding and extrusions materials.

ASTM Standard D-2657
This standard covers the procedures for heat-fusion bonding of polyolefin materials.

ASTM Standards D-2564 and F-493
These standards set forth requirements for PVC (D-2564) and CPVC (F-493) Solvent Cement including a resin material designation and resin content quality standard. Also included in these standards are test procedures for measuring the cement quality by means of burst and lap shear tests.

ASTM Standard F-656
This standard covers the requirements for primers to be used for PVC solvent cemented joints of pipe and fittings.

ASTM Standard D-2855
This standard describes the procedure for making joints with PVC pipe and fittings by means of solvent cementing. The following are standards of other groups that are commonly encountered in industrial thermoplastic piping design.

ANSI B1.20.1 (was B2.1)
(American National Standards Institute)
This specification details the dimensions and tolerance for tapered pipe threads. This standard is referenced in the ASTM standard for threaded fittings mentioned above.

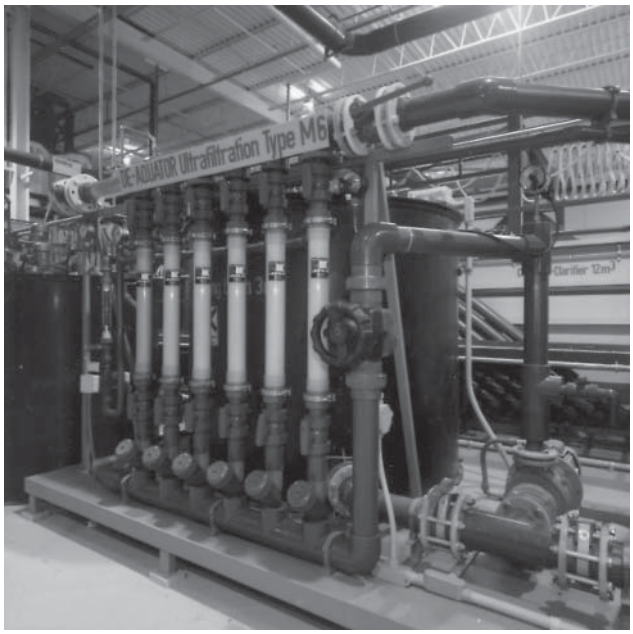
ANSI B16.5
This specification sets forth standards for bolt holes, bolt circle, and overall dimensions for steel 150# flanges.

NSF Standard 14
(National Sanitation Foundation)
This standard provides specifications for toxilogical and organoleptic levels to determine the suitability of plastic piping for potable water use. It additionally requires adherence to appropriate ASTM Standards and specifies minimum quality control programs. To meet this standard, a manufacturer must allow third party certification by NSF of the requirements of this standard.

Technical assistance regarding standards, applications, product performance, design, and installation tips are available from FABCO.

FABCO is also able to provide:

- Material and Performance Certification Letters
- Returned Product Evaluation
- Product, Installation, and Design Seminars
- Technical Reports on a variety of Subjects



CHEMICAL RESISTANCE GUIDE FOR VALVES & FITTINGS

This chemical resistance guide has been compiled to assist the piping system designer in selecting chemical resistant materials. The information given is intended as a guide only. Many conditions can affect the material choices. Careful consideration must be given to temperature, pressure and chemical concentrations before a final material can be selected. Thermoplastics and elastomers physical characteristics are more sensitive to temperature than metals. For this reason, a rating chart has been developed for each.

MATERIAL RATING FOR THERMOPLASTICS & ELASTOMERS
Temp. in °F = "A" rating, maximum temperature which material is recommended, resistant under normal conditions.
B to Temp. in °F = Conditional resistance, consult factory.
C = Not recommended.
Blank = No data available.

MATERIAL RATINGS FOR METALS
A = Recommended, resistant under normal conditions.
B = Conditional, consult factory.
C = Not recommended.
Blank = No data available.

Temperature maximums for thermoplastics, elastomers and metals should always fall within published temp/pressure ratings for individual valves. THERMOPLASTICS ARE NOT RECOMMENDED FOR COMPRESSED AIR OR GAS SERVICE. This guide considers the resistance of the total valve assembly as well as the resistance of individual trim and fitting materials. The rating assigned to the valve body plus trim combinations is always that of the least resistant part. In the cases where the valve body is the least resistant, there may be conditions under which the rate of corrosion is slow enough and the mass of the body large enough to be usable for a period of time. Such use should always be determined by test before installation of the component in a piping system. In the selection of a butterfly valve for use with a particular chemical, the liner, disc, and stem must be resistant. All three materials should carry a rating of "A". The body of a properly functioning butterfly valve is isolated from the chemicals being handled and need not carry the same rating.

ABS — (Acrylonitrile-Butadiene-Styrene) Class 4-2-2 conforming to ASTM D1788 is a time proven material. The smooth inner surface and superior resistance to deposit formation makes ABS drain, waste, and vent material ideal for residential and commercial sanitary systems. The residential DWV system can be exposed in service to a wide temperature span. ABS-DWV has proven satisfactory for use from -40°F to 180°F These temperature variations can occur due to ambient temperature or the discharge of hot liquids into the system. ABS-DWV is very resistant to a wide variety of materials ranging from sewage to commercial household chemical formulations. ABS-DWV is joined by solvent cementing or threading and can easily be connected to steel, copper, or cast iron through the use of transition fittings.

CPVC — (Chlorinated Polyvinyl Chloride) Class 23447-B, formerly designated Type IV, Grade 1 conforming to ASTM D-1784 has physical properties at 73°F similar to those of PVC, and its chemical resistance is similar to or generally better than that of PVC. CPVC, with a design stress of 2000 psi and maximum service temperature of 210°F, has proven to be an excellent material for hot corrosive liquids, hot and cold water distribution, and similar applications above the temperature range of PVC. CPVC is joined by solvent cementing, threading or flanging.

P.P. (Polypropylene) — (PP) Type 1 Polypropylene is a polyolefin which is lightweight and generally high in chemical resistance. Although Type 1 polypropylene conforming to ASTM D-2146 is slightly lower in physical properties compared to PVC, it is chemically resistant to organic solvents as well as acids and alkalies. Generally, polypropylene should not be used in contact with strong oxidizing acids, chlorinated hydrocarbons, and aromatics. With a design stress of 1000 psi at 73°F, polypropylene has gained wide acceptance where its resistance to sulfur-bearing compounds is particularly useful in salt water disposal lines, crude oil piping, and low pressure gas gathering systems. Polypropylene has also proved to be an excellent material for laboratory and industrial drainage where mixtures of acids, bases, and solvents are involved. Polypropylene is joined by the thermo-seal fusion process, threading or flanging. At 180°F., or when threaded, P.P. should be used for drainage only at a pressure not exceeding 20 psi.

PVC — (Polyvinyl Chloride) Class 12454-B, formerly designated Type 1, Grade 1. PVC is the most frequently specified of all thermoplastic materials. It has been used successfully for over 30 years in such areas as chemical processing, industrial plating, chilled water distribution, deionized water lines, chemical drainage, and irrigation systems. PVC is characterized by high physical properties and resistance to corrosion and chemical attack by acids, alkalies, salt solutions, and many other chemicals. It is attacked, however, by polar solvents such as ketones, some chlorinated hydrocarbons and aromatics. The maximum service temperature of PVC is 140°F. With a design stress of 2000 psi, PVC has the highest long term hydrostatic strength at 73°F of any of the major thermoplastics being used for piping systems. PVC is joined by solvent cementing, threading, or flanging.

CHEMICAL RESISTANCE GUIDE FOR VALVES & FITTINGS

PVDF — (KYNAR®) (Polyvinylidene Fluoride) is a strong, tough and abrasion resistant fluorocarbon material. It resists distortion and retains most of its strength to 280°F. It is chemically resistant to most acids, bases, and organic solvents and is ideally suited for handling wet or dry chlorine, bromine and other halogens. No other solid thermoplastic piping components can approach the combination of strength, chemical resistance and working temperatures of PVDF. PVDF is joined by the thermo-seal fusion process, threading or flanging.

EPDM — EPDM is a terpolymer elastomer made from ethylenepropylene diene monomer. EPDM has good abrasion and tear resistance and offers excellent chemical resistance to a variety of acids and alkalines. It is susceptible to attack by oils and is not recommended for applications involving petroleum oils, strong acids, or strong alkalines. It has exceptionally good weather aging and ozone resistance. It is fairly good with ketones and alcohols and has an excellent temperature range from -20°F to 250°F.

HYPALON® (CSM) — Hypalon has very good resistance to oxidation, ozone, and good flame resistance. It is similar to neoprene except with improved acid resistance where it will resist such oxidizing acids as nitric, hydrofluoric, and sulfuric acid. Abrasion resistance of Hypalon is excellent, about the equivalent of the nitriles. Oil and solvent resistance is somewhat between that of neoprene and nitrile Salts have little if any effect on Hypalon. Hypalon is not recommended for exposure to concentrated oxidizing acids, esters, ketones, chlorinated, aromatic and nitro hydrocarbons. Hypalon has a normal temperature range of -20°F to 200°F.

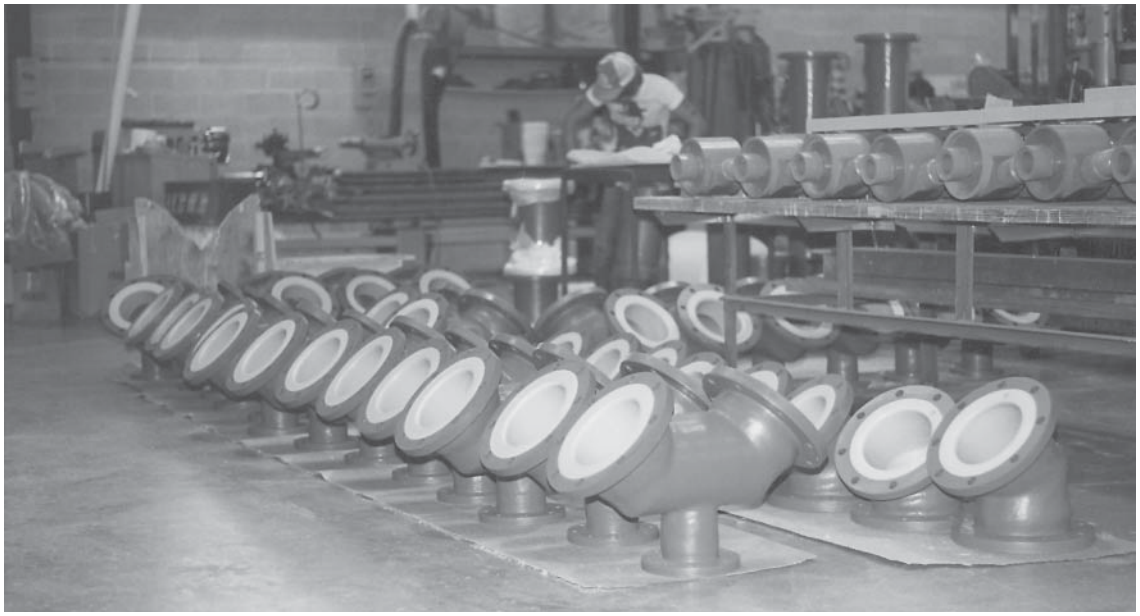
NEOPRENE (CR) — Neoprenes were one of the first synthetic rubbers developed. Neoprene is an all purpose polymer with many desirable characteristics and features high resiliency with low compression set, flame resistance, and is animal and vegetable oil resistant. Neoprene is principally recommended for food and beverage service. Generally, neoprene is not affected by moderate chemicals, fats, greases, and many oils and solvents. Neoprene is attacked by strong oxidizing acids, most chlorinated solvents, esters, ketones, aromatic hydrocarbons, and hydraulic fluids. Neoprene has a moderate temperature range of -20°F to 160°F.

NITRILE (NBR) — (BUNA-N) is a general purpose oil resistant polymer known as nitrile rubber. Nitrile is a copolymer of butadiene and acrylonitrile and has a moderate temperature range of -20°F to 180°F. Nitrile has good solvent, oil, water, and hydraulic fluid resistance. It displays good compression set, abrasion resistance and tensile strength. Nitrile should not be used in highly polar solvents such as acetone and methyl ethyl ketone, nor should it be used in chlorinated hydrocarbons, ozone or nitro hydrocarbons.

FLUOROCARBON (FKM) (VITON®) (FLUOREL®) — Fluorocarbon elastomers are inherently compatible with a broad spectrum of chemicals. Because of this extensive chemical compatibility, which spans considerable concentration and temperature ranges, fluorocarbon elastomers have gained wide acceptance as a material of construction for butterfly valve O-rings and seats. Fluorocarbon elastomers can be used in most applications involving mineral acids, salt solutions, chlorinated hydrocarbons, and petroleum oils. They are particularly good in hydrocarbon service. Fluorocarbon elastomers have one of the broadest temperature ranges of any of the elastomers, -20°F to 300°F, however, are not suitable for steam service.

TEFLON® (PTFE) — Polytetrafluoroethylene has outstanding resistance to chemical attack by most chemicals and solvents. PTFE has a temperature rating of -20°F to 400°F in valve applications. PTFE, a self lubricating compound, is used as a seat material in ball valves.

VITON is a registered trademark of the DuPont Company
TEFLON is a registered trademark of the DuPont Company
HYPALON is a registered trademark of the DuPont Company
KYNAR is a registered trademark of the Pennwalt Company
FLUOREL is a registered trademark of the 3M Company



FABCO PLASTICS

CHEMICAL RESISTANCE CHART

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS															
		ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Acetaldehyde CH3CHO	Conc.			120	C	C	350	200	C	C	C	C	B	C	C	C	C	C	B	B	A		B	B	A		A	A	A	A
Acetamide CH3CONH2				73		75	350	200	C	C	C	C	B		A		A		A	A			A	A	A	A	A	A	A	A
Acetic Acid CH3COOH	25%		73	180	140	200	350	140	C	200	C	C	C	C	C	C	C	C	C	C	C	C	C	A	A	A	A	A		A
Acetic Acid CH3COOH	60%		73		73	175	350	140	C		C	C	C	C	C	C	C	C	C	C	C	C	C	A	A	A	A	A		A
Acetic Acid CH3COOH	85%		C	120	73	150	350	140	C		C	C	C	C	C	C	C	C	C	C	C	C	C	A	A	A	A	A		A
Acetic Acid CH3COOH	Glac-ial		C	120	73	120	350	140	C		C	C	C	C	C	C	C	C	C	C	C	C	C	C	A	B	A	A		A
Acetic Anhydride (CH3CO)2O					C	C	350	C	70	200	B 70	C	B	C	C	C	C	C	C	C	C	C	C	C	B	B	B	B		A
Acetone CH3COCH3			C	73	C	C	350	130	C	B 70	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Acetophenone C6H5COCH3				120		C	350	140	C		C	C	C	C	C	C	C	C	C	C	C	C	C	C	C					
Acetyl Chloride CH3COCI		C				125	200	C	C	C	C	185	C	A	A	A	A	A	C	C	A		C		A	A	A	A		
Acetylene HC≡CH	Gas 100%	70		73	140	250	250	200	140	70	70	200	A	C	C	C	C	C	A	A	A	A	A	A	A	A	A	A	A	A
Acetylnitrile			C		C	150		C	C		70	C													A		A			A
Acrylic Acid H2C:CHCOOH	97%				C	150	200																							
Acrylonitrile H2C:CHCN			C		C	73	350	C	C	140	C	C	B		A	A	A	A	A	A	A	A	A	A	A	A	A	A		A
Adipic Acid COOH(CH2)4COOH	Sat'd		185		140	150	350	200	180	140	160	250	B	A					C	C	B		C		B 200		B	B 200		A
Allyl Alcohol CH2=CHCH2OH	96%				73	125	250	70	160	200	B 70	185			A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Allyl Chloride CH2CHCH2CI					C	212	350	C	C			70	C								C									
Aluminum Acetate Al(C2H4O2)3	Sat'd					275	350	200	B 70	C	C	C	C		C		C			C					A		A	B		
Aluminum Ammonium Sulfate (Alum) AINH4(SO4)212H2O	Sat'd			150	140	275	250	200	140			200	A	B	B	B	B	B			C			B	A		A	A		
Aluminum Chloride Aqueous AICI3	Sat'd		185	180	140	280	250	210	70	200	160	250	A	C	C	C	C	C	C	C	C	C	C	C	A	C	A	A		
Aluminum Fluoride Anhydrous AIF3	Sat'd				73	280	250	210	180	200	160	250		C	C	C	C	C	C	C	C		C	C	B	C	B	A		
Aluminum Hydroxide AIO3•3H2O	Sat'd		185		140	280	250	210	180		100	200		C	C	C	C	C	B	B	C		B	B	A	A	A	B		
Aluminum Nitrate Al(NO3)3•9H2O	Sat'd		185	180	140	280	250	210	180	100	100	100	C	C	C	C	C	C	C	C	C	C	C		A	A	A	C		
Aluminum Oxychloride					140	275						C																		
Aluminum Potassium Sulfate (Alum) AIK(SO4)2•12H2O	Sat'd			150	140	280	400	200	180	200	160	200	A	B	B	B	B	B			C			B	A		A	A		
Aluminum Sulfate (Alum) Al2(SO4)3	Sat'd		185	180	140	280	250	210	200	160	140	185	C	C	C	C	C	C	C	C	C		C	C		B				A
Ammonia Anhydrous NH3							250	200			100	C		C	C	C	C	C	A		A				A	A	A	A		A
Ammonia Gas NH3	100%		185	150	140	C	400	140	140	140	140	C	B	B	B			C	A		A				A	A	A	A		A
Ammonia Liquid NH3	100%			73	C	C	400	210	B 70	70	70	C	A	C	C	C	C	C			A			A	A	A	A	A		A
Ammonium Acetate NH4(C2H3O2)	Sat'd			73	140	175	400	140		140	140				C	C	C	C							B			B		
Ammonium Bifluoride NH4HF2	Sat'd		185		140	150	400	200	180			200		B 70	C			C	C	C	C	C	C	C	B	B	B	B		
Ammonium Bisulfide (NH4)HS					140	280	400		180																					
Ammonium Carbonate CH2O3•2H3N	Sat'd			180	140	280	400	210		140	140	250	B 212	B 70	C			C			A 140	C		B	B	B	B	B		A

CHEMICAL RESISTANCE CHART

		PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS																
CHEMICALS AND FORMULA	CONCENTRATION	ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Ammonium Chloride NH4Cl	Sat'd		185	180	140	280	400	210	180	200	160	250	B		C			C	C	C	C	C	C	C	B	C	B	B		B
Ammonium Dichromate (NH4)2Cr2O7					73	250		70	100	100	100																			
Ammonium Fluoride NH4F	10%				140	280	400	210	100	200	100		C	C	C			C			C				C					
Ammonium Flouride NH4F	25%				73	280	400	140					C	C	C			C			C				C					
Ammonium Hydroxide NH4OH	10%		185	180	140	225	400	210	B 70	200	70	70	B	C	C	C		C			C			B	A	A	A	B		A
Ammonium Nitrate NH4NO3	Sat'd	175	185	180	140	280	400	250	180	200	160	100		C	C	C		C								A	A	A		A
Ammonium Persulphate (NH4)2S2O8			73	150	140	73	200	210		70	70		C	C	C	C	C	C	C	C	C	C	C	B	A		A	C		A
Ammonium Phosphate (Monobasic) NH3H3PO4	All				140	280	400	210	100	140	140	185	B	C	C	C	C	C	B	B	C		B	A	A	A	A	B		A
Ammonium Sulfate (NH4)2SO4			185	180	140	280	400	210	180	200	160	200	C	C	C	C	C	C	B	B	C	B	B	B	B	B	A	B		A
Ammonium Sulfide (NH4)2S	Dilute					125	350	210	140	200	160		A	C	C	C	C	C	C	C	C		C		B		B	B		
Ammonium Thiocyanate NH4SCN	50-60%				140	275			70	70	70	185	B	C	C	C	C	C	C	C	C		C		A	A	A	B		A
Amyl Acetate CH3COOC5H11				C	C	125	100	B 70	C	C	C	C	A		B	B	B	B	B	B	B	A	B	A	A	A	A	A	A	A
Amyl Alcohol C5H11OH			73	180	C	280	400	210	B 140	200	140	185		A	A	A	A	A	B	B	B		B	A	A	A	A	A		
n-Amyl Chloride C_5H11CI					C	280	400	C	C	C	C	200	C		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Aniline $C_6H_5NH_2$			C	180	C	120	200	140	C	70	C	C	C	C	C	C	C	C	B	B	C	B	B	A	A	A	A	B		A
Aniline Chlorohydrate					C																									A
Aniline Hydrochloride C6H5NH2•HCl	Sat'd		C		C	75				C	C	185			C	C	C	C	C	C	C	C	C	C	C	C		A		
Anthraquinone C14H8O2					140							200							C	C	C									
Anthraqunone Sulfonic Acid C14H7O2•SO3H•3H2O					140							200																		
Antimony Trichloride SbCl3	Sat'd			180	140	73		140	140	140	140	185	C		C	C	C	C	C	C	C	C	C	C	C	C	A	A		
Aqua Regia (Nitro-hydrochloric Acid) $ClHHNO_3$			73		C	73	200	C	C	B 70	C	100	C		C	C	C	C	C	C	C	C	C		B		B			B
Argon Ar	Dry						350	200			100	200		A	A		A		A		A				A	A		A	A	
Arsenic Acid H3AsO4•1/2H2O	80%		185		140	280	400	185	160	200	180	200	C		C	C	C	C	C	C	C		C	B	A	B	A	A		A
Aryl Sulfonic Acid C6H5SO3H					140			140				185																		
Asphalt			C		C	250	350	C	B 70	C	C	180	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B		A
Barium Carbonate BaCO3	Sat'd				140	280	400	250	180	200	160	250			A	A	A	A	B	B	B	B	B	A	A	A	A	A		
Barium Chloride BaCl2•2H2O	Sat'd				140	280	400	250	180	200	160	300		A	A	A	A	A	B	B	C	B	B	B	A		A	A		
Barium Hydroxide Ba(OH)2	Sat'd				140	280	400	200	180	200	140	300			C	C	C	C	B	B	C		B	A	A	A	A	A		A
Barium Nitrate Ba(NO3)2	Sat'd				73	275	250	200	180	200	160	300			C	C	C	C	A	A	A		A		A		A			
Barium Sulfate BaSO4	Sat'd		185		140	280	400	200	100	200	160	300			B	B	B	B	B	B	A		B	A	A	A	A	A		
Barium Sulfide BaS	Sat'd				140	280	400	140	C	200	160	300		C	C	C	C	C	B	B	C		B	A	A	A	A	A		
Beer		C		180	140	200	300	200	70	200	140	200	A	A	A	A	A	A	C	C	C		C	A	A	A	A	A		

CHEMICAL RESISTANCE CHART

		PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS																
CHEMICALS AND FORMULA	CONCENTRATION	ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Beet Sugar Liquors				180	140	225		210	100	200	160	185	A				A		B	B	B				A	A	A	A		
Benzaldehyde C6H5CHO	10%	C		73	73	70		140	C	C	C	C		A	A	A	A	A	C	C	B		C	A	A	A	A	B		A
Benzene C6H6		C	C	C	C	170	250	C	C	C	C	150		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Benzene Sulfonic Acid C6H5SO3H	10%			180	140	125		C	C	180	100	185			B	B	B	B	C	C	C		C	B	B	B	A	A		
Benzoic Acid C6H-5COOH	All			73	140	230	350	C	C	200	160	200			C	C	C	C	C	C	C		C	A	A	A	A	A		A
Benzyl Alcohol C6H-5CH2OH				150	C	250		C	C	140	B to 140	B to 140		A	A	A	A	A	B	B	B		B	A	A	A	A	A	A	
Bismuth Carbonate (BiO)2CO3					140				70	100	70																			
Black Liquor	Sat'd		185		140	175	225	180	180	70	70	200			C	C	C	C	B	B	B		B	B	A	B	A	B		
Bleach	5% Active Cl2		180	120	140	280	200	140	C			185			C	C	C	C	C	C	C		C	B	A	B	A	A		A
Bleach	12% Active Cl2	C	180	C	140	280	200	140	C	70		185			C	C	C	C	C	C	C		C	B	A	B	A	A		A
Blood							200		70	70	70	70			B		B		C	C			B		A	A	A	A		A
Borax Na2B4O7•10H2O	Sat'd			180	140	280		210	140	200	140	185			A	A	A	A	A	A	B	A	A	A	A	A	A	A	A	A
Boric Acid H3BO3	Sat'd		185	180	140	280		210	140	200	140	185			B	B	B	B	C	C	B		C	B	A	B	A	A		A
Brake Fluid							300	140	C			C			B				B	B	A		B	A	A	A	A	A		
Brine	Sat'd		185	180	140	280	400	250	180	180	160	300			A	A	A		C	C	C	B	C	B	A	B	A	A		A
Bromic Acid HBrO3			185		140	200		70				70	C	C	C	C	C	C												
Bromine Br2	Liquid	C		C	C	150		C	C	70	C	70	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C		A
Bromine Br2	Vapor	C		C	140	150		C	C	70	C	70	C	C	C	C	C	C	C	C	C	C	C	C	C	C	A	A		A
Bromine Water	Cold Sat'd	C		C	140	212		C	C	70	C	185	C	C	C	C	C	C	C	C	C		C							
Bromotoluene C7H7Br					C	150		C				150																		
Bromotoluene C6H-5CH2B2				C	C	175																								
Butadiene H2C:CHHC:CH2	50%		73		140	250	350	C	C	B to 140	140	185	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Butane C4H10	50%			73	140	250	350	C	70	200	70	185	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Butyl Acetate CH3COOCH(CH3) (C2H5)			73	C	C	73	175	140	C	C	C	C			B	B	B	B	B	B	B		B	A	A	A	A	A		A
Butyl Alcohol CH3(CH2)2CH2OH		C	73	100	100	225	300	200	B to 140	140	140	75		B	B	B	B			B			A	A	A	A	A			
Butyl Cellosolve HOCH2CH2OC4H9					73		200	140	C	100		C			A	A	A	A	A	A			A	A	A	A	A	A	A	
n-Butyl Chloride C4H9CI						280	400	C	C	C	C	100			B	B	B	B	B	B	B		B	B	B	B	B	B		
Butylene (C) CH3CH:CHCH3	Liquid				140	280	400	C	70	C	C	100			A	A	A	A			A			A	A	A	A	A	A	A
Butyl Phenol C4H-9C6H4OH					73	230				B to 70	C																			
Butyl Phthalate				180								70																		
Butyl Stearate CH3(CH2)16CO2 (CH2)3CH3					73	100	250	C	100		C	185			A	A	A	A	B	B			B	A	A	A	A			
Butynediol HOCH2C:CCH2OH					73					100	B to 70																			

CHEMICAL RESISTANCE CHART

		PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS																	
CHEMICALS AND FORMULA	CONCENTRATION	ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Butyric Acid CH3CH-2CH2COOH				180	73	230	300	140		C	C	70			A	A	A	A	C	C	C	C	C	B	A	A	A	A		
Cadmium Cyanide Cd(CN)2			185		140						70																			
Calcium Bisulfide Ca(HS)2•6H2O					C	280	200		100	C		185													A		A			
Calcium Bisulfite Ca(HSO3)2			185	180	140	280	350	C	70	200	70	185			C	C	C	C	C	C	C		C	B	A		A	C		A
Calcium Carbonate CaCO3			185	180	140	280	350	210	100	70	70	300		A	C	C	C	C	B	B	B		B	A	A	A	A	A		A
Calcium Chlorate Ca(ClO3)2•2H2O					140	280	350	140	70	70	70	185		C	B	B	B	B	B	B	B	B	B	B	A		A	A		
Calcium Chloride CaCl2		100	185	180	140	280	350	210	100	200	160	250		B	B	B	B	B	A	A	C		C	B	A	B	A	A	B	A
Calcium Hydroxide Ca(OH)2			185	180	140	280	250	210	140	200	70	250	C	C	C	C	C	C	C	C	C		C	A	A	A	A	A		A
Calcium Hypochlorite Ca(OCl)2	30%		185	150	140	200	200	70	C	140		185	C	C	C	C	C	C	C	C	C		C	B	B	B	B	C		B
Calcium Nitrate Ca(NO3)2				180	140	280	200	210	180	100	100	200		B	B	B	B	B	B	B			B		A		A	A		
Calcium Oxide CaO					140	250		210	180	200	160								A	A	B				A	A	A			
Calcium Sulfate CaSO4		100			140	280	200	210	180	200	160	200		A	A	B	B	B	A	A	B	A	A	A	A	A	A	A	A	A
Camphor C10H16O		C			73		350	210	100	70	C	250			B	B	B	B	B	B	B		B	A	A	A	A	B		
Cane Sugar C12H22O11				73	140	275	400	250	180	100	160	200			A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Caprylic Acid CH3(CH2)6COOH						175	350												A	A	B		A		A		A			
Carbitol					73		200	70	70	70	70	100			B	B	B	B	B	B	B		B		B		B	B		
Carbon Dioxide CO2	Dry 100%	100	185	150	140	280	400	200	180	200	160	200	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	
Carbon Dioxide CO2	Wet	100	185	150	140	280	400	210	180	200	160	200	A	A	A	A	A	A	B	B	B	B	B	A	A	A	A	A	A	A
Carbon Disulfide CS2				C	C	73	200	C	B to 70	C	C	70		C	B	B	B	B	A	A	A		A	A	A		A	A		A
Carbon Monoxide CO	Gas		185		140	275	400	250	70	200	70	250	A		A	A	A	A	A	A	B		A	A	A	A	A	A		A
Carbon Tetrachloride CCl4		C	73	C	73	280	350	C	C	C	C	185		B	A	A	A	A	C	C	A		C	A	A	A	A	A		A
Carbonic Acid H2CO3	Sat'd		185		140	280	350	210	180	70	70	200			C	C	C	C	B	B	B	B	B	A	A	A	A	A	B	
Castor Oil			185		140	280	350	140	140	150	100	140	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Caustic Potash KOH	50%		185		140	280	350	200	180	200	160	C									B			A	A	A	A	A		
Caustic Soda NaOH (Sodium Hydroxide)	Up to 40%	70	210	180	100	C	350	180	C	140	160	C	C	B	B	C	C	C	B	B	B	B	B	A	A	A	A	A		
Cellosolve C4H10O2					73	280	200	140	C	70		C			A	A	A	A	A	A	A		A		A		A		A	
Cellosolve Acetate CH3COOCH2CH2O C2H5					73		300	140	C	C	C	C	B		B		B			B					B		B			A
Chloral Hydrate CCl3CH(OH)2	All				140	75				70	B to 70	C																		
Chloramine NH2Cl	Dilute				73					70	70				B	B	B	B	C	C	C				B		B	B		
Chloric Acid HClO3•7H2O	10%				140		140			200	140	140			C	C	C	C	C	C	C	C	C	C	B	C	A	C		
Chloric Acid HClO3•7H2O	20%				140		140					100			C	C	C	C	C	C	C	C	C	C	C	C	A	C		
Chlorine Gas (Dry) (Moisture Content)	0-20 PPM			C	73	200	400	C	C	C	C	185	C	C	C	C	C	C	B	A*	A*	B	B	B	A		A	A		A

Note: * Ratings are for body material only.

FABCO PLASTICS

CHEMICAL RESISTANCE CHART

		PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS																
CHEMICALS AND FORMULA	CONCENTRATION	ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Chlorine Gas (Moisture Content)	20-50 PPM	C		C	C	200	400	C	C		C	185	C	C	C	C	C	C	C	C	A*	C	C	C	A*		C	A		A
Chlorine Gas (Moisture Content)	50+ PPM	C		C	C	200	400	C	C		C	185	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	A		A
Chlorine	Liquid	C	C	C	C	200		C		B to 70	C				B	B		B	C	C	C		C	C	C	C				
Chlorinated Water	10 ppm		73		140	230	400	210	140	B to 70	C	185	C	C	B	B	C	C			C		C	B	A	A	A	A		A
Chlorinated Water	Sat'd		73		140	230	400	70	C	B to 70	C	185	C	C	C	C	C	C			C			C	A	B	A	B		A
Chloroacetic Acid CH2ClCOOH	50%				140	C	200	70	C	200	C	C	C	C	C	C	C	C	C	C	C		C	C	C	C	B	B		
Chloroacetyl Chloride ClCH2COCl					73	125																								
Chlorobenzene C6H5Cl	Dry			73	C	170	200	C	C	C	C	70			A	A	A	A	C	C	B		C	A	A	A	A	A		A
Chlorobenzyl Chloride ClC6H4CH2Cl					C	125																			A		A			
Chloroform CHCl3	Dry		C	C	C	125	200	C	C	C	C	70			A	A	A	A	C	C	C		C	A	A	A	A	A	A	
Chloropicrin CCl3NO2					C	150																								
Chlorosulfonic Acid ClSO2OH				C	73	C	200	C	C	C	C	C	C	C	C	C	C	C	B	B	C	C	B	C	C	C	B	A		A
Chromic Acid H2CrO4	10%		210	150	140	175	350	70	C	140		100	C	C	C	C	C	C	C	C	C	C	C	B to 212	Ato 70		Ato 125	B		A
Chromic Acid H2CrO4	30%		210	150	140	175	350	C	C	140		100	C	C	C	C	C	C	C	C	C	C	C	B to 212	B to 70		Ato 125	C		A
Chromic Acid H2CrO4	40%		210	150	140	175	300	C	C	140		140	C	C	C	C	C	C	C	C	C	C	C	C	B to 70			C		A
Chromic Acid H2CrO4	50%		210	C	C	180	200	C	C	140		140	C	C	C	C	C	C	C	C	C	C		C	B to 70		B to 212	C		B
Chromium Potassium Sulfate CrK(SO4)2•12H2O			73	140	73	200		140	180	200	160	200								C					B	B	A	B		
Citric Acid C6H8O7	Sat'd		185	180	140	275	200	210	70	140	140	200		C	C	C	C	C	C	C	C		C	B	A	A	A	A		A
Cocunut Oil				73	140	280	400	C	70	B to 140	100	185			B	B	B	B	C	C	B		C	B	A		A	B		
Coffee								140	100			200		A	A	A	A	A	C	C	C			A	A	A	A		A	
Coke Oven Gas				73	140	230	400	70	B to 70	140		185			B	B	B	B	A	A	A	A	A	A	A	A		B		
Copper Acetate Cu(C2H3O2)2•H2O	Sat'd		73	73	73	250	350	100	180	C	160	140			C	C	C	C	C	C	C		C	B	A		A	B		A
Copper Carbonate CuCO3	Sat'd				140	280	350	210				185												B	A		A	A		
Copper Chloride CuCl2	Sat'd		185		140	280	350	210	180	200	160	200	C	C	C	C	C	C	C	C	C	C	C	B	A		A	B		A
Copper Cyanide Cu(CN)2			185		140	275	350	210	180		160	185		C	C	C	C	C	C	C	C	A	C	B	A		A	B		
Copper Fluoride CuF2•2H2O	2%				140	280		210	B to 70	140	140	185																		
Copper Nitrate Cu(NO3)2•3H2O	30%				140	280		210	B to 70	200	160	200	C	C	C	C	C	C	C	C	C		C	B	A		A	C		
Copper Sulfate CuSO4•5H2O	Sat'd		185	120	140	280		210	180	200	160	200	C	C	C	C	C	C	C	C	C		C	A	A	A	A	C		A
Corn Oil			C	73	73	275	400	C	180	C	C	300		A	B	B	B	B	B	B	B	B	B	A	A	A	A	B		
Corn Syrup				150	140	250			100	200	100	185																		
Cottonseed Oil			185	150	140	280	400	C	180	200		185		A	B	B	B	B	B	B	B		B	A	A	A	A	B		
Creosote			73		73		350	C	73	73	C	73		B	B	B	B	B	A	A	A	A	A	A	A	A	A	A	A	A

CHEMICAL RESISTANCE CHART

		PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS																
CHEMICALS AND FORMULA	CONCENTRATION	ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Cresol CH3C6H4OH	90%			73	C	150	200	C	C	B to 140	C	100													B			B		
Cresylic Acid C7H8O	50%				140	150	200	C	C	C	C	185		A	A	A	A	A	A	A	B	A	A	A	A	A	A	A	A	
Croton Aldehyde CH3CH:CHCHO					C	125	200		C		70	C																		
Crude Oil			185		140	280	400	C	70			200		C	C	C	C	C	C	C	B			A	A	A	A	B		
Cumene C6H5CH(CH3)2						100	300	C	C	C	C	200									B				B		B	B		A
Cupic Fluoride CuF2					140	280		210																						
Cupric Sulfate CuSO4•5H2O	Sat'd	100		73	140	280	250	210	180	140	160	200																		
Cuprous Chloride CuCl	Sat'd	70			140	250	350	200	180	70	70	200		C	C			C												
Cyclohexane C6H12		100	C	C	C	280	300	C	C	C	C	185			A	A	A	A	B	B	A		B	A	A	A	A	A	A	A
Cyclohexanol C6H11OH		100	C	120	C	150	250	C	C	C	C	185							A	A			A	A	A	A	A			
Cyclohexanone C6H10O			C	C	C	73	200	70	C	C	C	C			B	B	B	B	B	B	B		B	B	A		A	B		A
Decahydronaphthalene C10H18							400	C	C	C	C	200																		
Detergents (Heavy Duty)		C	185	150	140			250	180	200	160	210		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	
Dextrin (Starch Gum)	Sat'd				140	250	200	C	180			200		A	A	A	A	A	B	B	B				A		A			
Dextrose C6H12O6					140	275	400	140	180	140	160	200			A	A			A						A		A			
Diacetone Alcohol CH-3COCH2C (CH3)2OH			C	120	C	70	350	70	C		C	C		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Dibutoxyethyl Phthalate C20H30O6					C			B to 70	C	140	C	200			A	A	A	A	A	A	A		A		A		A			
n-Dibutyl Ether C4H9OC4H9						100	350	C	C	C	C	C																		
Dibutyl Phthalate C6H4(COOC4H9)2				120	C	C	350	70	C	C	C	C			A	A	A	A	A	A	A				A		A			
Dibutyl Sebacate C4H9OCO(CH2)8 OCOC4H9					73	C	350	70	C	C	C	C																		
Dichlorobenzene C6H4Cl2					C	150		C	C	C	C	150							A	A			A		A		A			
Dichloroethylene C2H4Cl2				C	C	225	350	C	C	C	C	185					B			B					B			A		
Diesel Fuels					140	280	350	C	70	C	C	185		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	
Diethylamine C4H10NH					C	73	200	70	70			C		C	C	C	C	C	A	A	C			A	A	A	A	B		
Diethyl Cellosolve C6H14O2						280		C	140		100	200							A	A			A		A		A			
Diethyl Ether C4H10O				73	73	73		C				C																		
Diglycolic Acid O(CH2COOH)2	Sat'd				140	73	250	70	70			70																		
Dimethylamine (CH3)2NH				120	140	75		140	C	C	C	C							C						A		A			
Dimethyl Formamide HCON(CH3)2			C	120	C	C	250	C	100	100	C	C			B	B	B	B	B	B	B				A		A	A		
Dimethylhydrazine (CH3)2NNH2					C	C						C																		
Dinonyl Phthalate C6H4(COOC9H19)2							32	B to 10	C	C	C	B to 10																		
Dioctyl Phthalate C6H4(COOC8H17)2			C	C	C	75	200	70		C	C	70			A	A	A	A	C	C	C									

Note: * Ratings are for body material only.

CHEMICAL RESISTANCE CHART

		PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS																
CHEMICALS AND FORMULA	CONCENTRATION	ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Dioxane O:(CH2)4:O		C		73	C	C		70	C	C	C	C			A	A	A	A	A	A	A				A		A	A		
Diphenyl Oxide (C6H5)2O	Sat'd					125		C	C		C	300			A	A	A	A	A									A		
Disodium Phosphate Na2HPO4			185		140	200	400	210	100	140					B	B	B	B	B	B					A		A	B		
Dow Therm A C12H10•C12H10O					C		212	C	C	C	C	C			A	A	A	A	B	A	A		A	A	A	A	A	A	A	
Ether C4H10O			C	73	C	125			C	C	C	C		A	A	A	A		B	B	B	A	A	A	A	A	A	A	A	
Ethyl Acetate CH-3COOC2H5		C		120	C	C	200	70	C	C	C	C			A	A	B		A	A	A			A	A	A	A	A	B	A
Ethyl Acetoacetate CH-3COCH2COOC2H5		C			C	73	200	100	C			C																		
Ethyl Acrylate CH2:CHCOOC2H5			C		C	73	350	70	C	C	C	C			A	A			A	A	A		A	A	A	A	A	A	A	A
Ethyl Alcohol (Ethanol) C2H5OH			140	180	140	280	300	170	180	200	70				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Ethyl Benzene C6H5C2H5				C	C	125	350	C	C	C	C	70			B	B			B	B	B		B		A		A	A		A
Ethyl Chloride C2H5Cl	Dry			73	C	280	350	B to 70	C	70	B to 70	140			A	A	B		A	A	A	A	A	A	A	A	A	A	B	A
Ethyl Chloroacetate CH2ClCO2C2H5					C	75																								
Ethylene Bromide BrCH2CH2Br	Dry				C	280	350		C			B to 70			A					A	A				A		A	A		A
Ethylene Chloride ClCH2CH2Cl	Dry	C		73	C	280	350		C	C		70													A		A	A		
Ethylene Chlorohydrin ClCH2CH2OH				73	C	73	200	70	C	70	70	C										A								
Ethylene Diamine NH2CH2CH2NH2		C		120	C	225		70	100	100	100			A	A	C		A	A	B				A		A	B			
Ethylene Dichloride C2H4Cl2	Dry	C		73	C	280	350	C	C	C	C	120			A	A			A	A	A		A		A	A	A	A	A	
Ethylene Glycol CH2OHCH2OH		73	185	120	140	280		210	180	200	160	250		A	A	A	A	A	A	A	A		A	A	A	A	A	A	A	A
Ethylene Oxide CH2CH2O				C	C	C	400	C	C	C	C	C			A	A			B	A	A		A		A		A	B		A
Ethyl Ether (C2H5)2O				C	C	125	250	C	C	C	C	C																		A
Ethyl Formate HCOOC2H5						73			C		70	C			A	A			A	A			A		A		A			
2-Ethylhexanol CH3(CH2)3CHC2H5 CH2OH						250				70	C																			
Ethyl Mercaptan C2H5SH						75				C										A	A				A		A	A		
Ethyl Oxalate (COOC2H5)2								140	C		C																			
Fatty Acids R-COOH			73	120	140	280	400	C	140	C	140	185	C		C	C	C	C	C	C	C		C		A		A	A		A
Ferric Chloride (Aqueous) FeCl3	Sat'd		185	180	140	280	400	225	180	200	160	200	C	C	C	C	C	C	C	C	C	C		C	C	C	C	C		A to 175
Ferric Hydroxide Fe(OH)3	Sat'd		185	180	140	250	400	180	100	100	100	180	C	C					C	C			C		A		A	A		
Ferric Nitrate Fe(NO3)3•9H2O	Sat'd		185	180	140	280	400	210	180	140	160	200		C	C	C	C	C	C	C	C		C	B	A	A	A	C		A
Ferric Sulfate Fe2(SO4)3				180	140	280	200	210	140	140	140	185		C	C	C	C	C	C	C	C		C	B	A	A	A	C		
Ferrous Chloride FeCl2	Sat'd		185	180	140	280	400	200	180			200	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C			B
Ferrous Hydroxide Fe(OH)2	Sat'd		185	180	73	250	400	180	180			180	C						C						A					
Ferrous Nitrate Fe(NO3)2			140	140	73	280	400	180	180	140	160	200													A	A	A			

CHEMICAL RESISTANCE CHART

		PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS																
CHEMICALS AND FORMULA	CONCENTRATION	ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Ferrous Sulfate FeSO4		70	185	180	140	280	400	200	180	140	160	200		B	C	C	B		C	C	C	C	C	A	A	A	A	A		A
Fish Oil					140		300	C	70	C		70		A	A	A	C		B	A	A		A	A	A	A	A	A	A	
Flue Gas								C	180			300			A	A			A	A	A		A	A	A	A	A	A	A	
Fluoboric Acid HBF4			73	73	140	275	350	140	160	140	160	140	C	C	B	B			C	C			C		A		A	A		
Fluorine Gas (Dry) F2	100%		73	C	73	73	C		C	140	C	C			B	B			C	C	A				A	A	A	A		A
Fluorine Gas (Wet) F2					73	73	C	70				100			C	C			C	C	C				A	A	A	A		
Fluosilicic Acid H2SiF6	50%		73		140	280	300	140	100	200	100	210	C	C	B	B			C	C	C		C	B	B	B	A	A		A
Formaldehyde HCHO	Dilute			120	140	125	300	140	C	200	140	C			A	A	B		C	C	B			A	A	A	A	A		A
Formaldehyde HCHO	35%		73	180	140	125	300	140	C	150	140	C			A	A	B		C		B			A	A	A	A	A		A
Formaldehyde HCHO	37%		73	180	140	125	300	140	C	C	100	C			A	A	B		C		B			A	A	A	A	A		A
Formaldehyde HCHO	50%		73		140		300	140	C	C	140	C			B	B	B		C		B			B	A	A	A	A		A
Formic Acid HCOOH			73	73	73	250	300	200	C	70	140	C			C	C	B		C	C	C	B	C	A	A	A	A	A		A
Formic Acid Anhydrous HCOOH			73	180					C	160	100	C													A		A	A		
Freon 11 CCl3F	100%	C	73		140	200	300	C	70	130	C	70		A	A	A	A	A	B	B	B		B	A	A	A	A	A		
Freon 12 CCl2F2	100%		73	73	140	200	C	C		130	130	C		A	A	A	A	A	B	B	B		B	A	A	A	A			
Freon 21 CHCl2F	100%				C	200	300	C	C		C	C		A	A	A	A	A	B	B	B		B	A	A	A	A			
Freon 22 CHClF2	100%			73	C	200	C	C	C	130	130	C		A	A	A	A	A	B	B	B		B	A	A	A	A			
Freon 113 C2Cl3F3	100%				140	200	300	C	130	130	130	130		A	A	A	A	A	B	B	B		B	A	A	A	A			
Freon 114 C2Cl2F4	100%				140	200	300	C	130	70	70	C		A	A	A	A	A	B	B	B		B	A	A	A	A			
Fructose C6H12O6			185		140	280	300	175	140	140	160	225							A	A			A	A	A	A	A	A		
Furfural C4H3OCHO				C	C	75	300	140	C	70	70	C		A	A	A	A	A	A	A	A		A	A	A	A	A	A		A
Gallic Acid C6H2(OH)3CO2H			73		140	75	300	70	C	70	70	185			B	B	C		C	C	C		C	A	A	A	A	A		A
Gasoline, Leaded		C	C	C	140	275	200	C	70	70	70	100	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Gasoline, Unleaded		C	C	C	140	280	200	C	70	70		100	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Gasohol		C		C	140	280	200	C	70			100	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Gasoline, Sour		C		C	140	280	200	C	70			100			B	B			A	A	A		A	B	A	A	A	C		A
Gelatin			150	180	140	250	300	200	180	200	160	250			C	C	B		C	C	C		C	C	C	A	A			
Glauber's Salt Na2SO4•10H2O							200	70	C	100	160	200			A	A		A	A	A			A	A	A	A	A	A	A	
Glucose C6H12O6•H2O		180	185	180	140	280	400	250	180	200	160	300	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Glue						250	400	100	140	200	160	250	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Glycerin C3H5(OH)3		140	185	180	140	280	400	200	70	200	160	300	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Glycol OHCH2CH2OH			185		140	280	300	200	140	200	160	250			A	A			A	A	A		A	A	A	A	A	A		A

CHEMICAL RESISTANCE CHART

		PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS															
CHEMICALS AND FORMULA	CONCENTRATION	ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Glycol Amine															C	C	C		A	A	A		A		A		A			
Glycolic Acid OHCH-2COOH	Sat'd			73	140	73	200		C	C	70	C			B	B			C	C	C		C		A		A	B		
Glyoxal CHOCHO									C	C	70				B	B	B		C	C	C		C		A	A	A	B		
Grape Sugar C6H12O6					140			250	180	200	160	185																		
Grease								C	150	C	100	200			C	C	C	C	A	A	A		A		A	A	A	A	A	A
Green Liquor								150	150	70	70				C	C	C		A	A		A	A		A	A	A	A		
Gypsum CaSO4•2H2O	Slurry					275	350	210	180	200	160	200		A	A	A	B	B	A	A	B	A	A	A	A	A	A	A		A
Heptane C7H16				C	140	280	300	C	70	70	70	185			A	A	A		A	A	A	A	A	A	A	A	A	A	A	A
n-Hexane C6H14		C	73	73	73	280	300	C	70	70	70	70			A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	
Hexanol CH3(CH2)4CH2OH					100	175	300	C	70	70	B to 70	160			A	A	A		A	A	A		A	A	A	A	A	A	A	A
Hydraulic Oil (Petroleum)					73		300	C	160	70	70	250			A	A	B		A	A	A		A	A	A		A	A	A	
Hydrazine H2NNH2					C	200	250	70	70	70		C			C	C	C	C	C	C	C		C		A		A	A		
Hydrobromic Acid HBr	20%		73	120	140	280	250	140	C	100	B to 70	185	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	
Hydrobromic Acid HBr	50%			140	140	280	250	140	C	100	B to 70	185	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	
Hydrochloric Acid HCl	35%	C	210	150	140	280	250	70	C	100		100	C	C	C	C	C	C	C	C	C	C	C	C	B	C	B	C	C	
Hydrochloric Acid HCl	37%	C	210	150	140	280	250	70	C	100		70	C	C	C	C	C	C	C	C	C	C	C	C	B	C	B	C	C	
Hydrocyanic Acid HCN	10%			73	140	280	250	200	70	200		185	C	C	C	C	C	C	C	C	C	C	C	C	A	B	A	A	C	A
Hydrofluoric Acid HF	Dilute		73	180	73	250	300	C	C	150	70	150	C	C	C	C	C	C	C	C	C	C	C	C	C	C	B	A	C	A
Hydrofluoric Acid HF	30%			120	73	250	300	C	C	150	70	150	C	C	C	C	C	C	C	C	C	C	C	C	C	C	B	A	C	A
Hydrofluoric Acid HF	40%	C	C	150	73	250	300	C	C	140	C	100	C	C	C	C	C	C	C	C	C	C	C	C	C	C	B	B	C	A
Hydrofluoric Acid HF	50%	C	C	100	73	200	300	C	C	140	C	70	C	C	C	C	C	C	C	C	C	C	C	C	C	C	B	B	C	A
Hydrofluosilicic Acid H2SiF6	50%		140	140	140	280	300	140	170	150		200	C	C	B	B			C	C	C		C	B	B	B	A	A		
Hydrogen H2	Gas		73	73	140	280	300	250	180	200	160	300	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Hydrogen Cyanide HCN					140	280			70	100	70																A			
Hydrogen Fluoride Anhydrous HF			C	73	C	200	250	70	C			C													A	A	A			A
Hydrogen Peroxide H2O2	50%		185	150	140	150	300	100	C	200	C	185	C	C	C	C	C	C	C	C	B	C	C	A	A	A	A	A		
Hydrogen Peroxide H2O2	90%				140	73	300	C	C	200	C	100	C	C	C	C	C	C	C	C	B	C	C	A	A	A	A	B		B
Hydrogen Phosphide PH3					140	150																								
Hydrogen Sulfide H2S	Dry		185	150	140	280		100	C	140	C	140	B		B				B		B				A	B	A	A		A
Hydrogen Sulfide H2S	Wet				140	225		100	C	70	C	140	C	C	C	C	C	C	C	C	C		C	C	A	C	A	B		B
Hydrogen Sulfite H2SO3								70	C	70		100		C	C	C	C	C	C	C	C		C	C	A		A	A		
Hydroquinone C6H4(OH)2	Sat'd				140	250	300	C	70		C	185									A				A		A	A		

CHEMICAL RESISTANCE CHART

		PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS																	
CHEMICALS AND FORMULA	CONCENTRATION	ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Hydroxylamine sulfate (NH2OH)2•H2SO4					140			70			70																			
Hypochlorous Acid HOCI	10%		140	73	140	70	300	70	C			70		C																
Inks							300		70		70	70			A	A	A		C	C	C		C		A		A	A		
Iodine I2	10%		73	150		150	200	70	70	70	C	70		C	C	C	C	C	C	C	C		C	C	C	C	B	A		A
Iron Phosphate FeH3PO4												180		C	C	C	C	C					B	A	A	A	A	C		
Isobutane (CH3)2CHCH3							140	C	70	C	C	B to 70		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Isobutyl Alcohol (CH3)2CHCH2OH						250	300	140	70	70	70	140													A		A			
Isooctane (CH3)3CCH2CH(CH3)2				73		250	300	C	70	200	70	185		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Isophorone C(O) CHC(CH3)CH2C (CH3)2CH2						175		C	C			C																		
Isopropyl Acetate CH3COCOCH(CH3)2		C					200	70	C	C	C	C		A	A				A	A	A		A	A	A	A	A	A	A	
Isopropyl Alcohol (CH3)2CHOH		C		180	140	140	300	140	70	200	70	160		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	
Isopropyl Chloride CH3CHCICH3						100	200	C	C		C	70																		
Isopropyl Ether (CH3)2CHOCH(CH3)2			C		C	125	140	C	70	C	C	C			A	A		A	A	A	A	A	A	A	A	A	A	A	A	A
JP-3 Fuel							200	C	70	C	C	185		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
JP-4 Fuel			73		140	200	300	C	70	C	C	300		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
JP-5 Fuel			73		140	200	300	C	70	C	C	300		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
JP-6 Fuel							200	C	100	C	C	100		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Kelp Slurry								C	70	C		100			B	B	B	B	B	B	B		B	A	A	A	A	A	A	
Kerosene		B to 70	185	73	140	280	250	C	140	C	70	300	70	A	A	A	A	A	A	A	A	A	A		A	A	A	A	A	A
Ketchup					73		250	210	140	B to 70		200	C		C	C	C		C	C	C		C	B	A	A	A	A		
Ketones		C	C		C	C	200	C	C	C	C	C			A	A	A		A	A	A		A	A	A	A	A	A	A	
Kraft Liquors		100	185		140		250		70	70	70	100			C	C	C	C	C	C	C		C		A		A			
Lactic Acid CH-3CHOHCOOH	25%			150	140	125	300	70		140	140	70			C	C	C	C	C	B	C		B	A	A	A	A	A		
Lactic Acid CH-3CHOHCOOH	80%			150	73	125	300	70	C	140		70			C	C	C	C	C	B	C		B	A	A	A	A	A		A
Lard Oil			185	73	140	280	300	C	140	C	70	185		C	C	C	C	C	B	B	B		B		A		A	B		
Latex (C2H6OSi)x							200	70	70		100	70		A	A				A	A			A		A		A			
Lauric Acid CH3(CH2)10COOH					140	225	300		70			100							C	C			C		A		A			
Lauryl Chloride C12H25CI							300	140	70			200							C	C			C		A		A			
Lead Acetate Pb(C2H3O2)2•3H2O	Sat'd		185	180	140	280	300	210	70	100	160	C			C	C			C	C	C		C		A		A	A		
Lead Chloride PbCl2				73	140	250	300	C	100	100	70	140																		
Lead Nitrate Pb(NO3)2	Sat'd		185	180	140	250	300	175	180		140	225									A				A		A			
Lead Sulfate PbSO4			185	150	140	250	300	210	180	200	140	225			B	B			C	C	C		C		B		B	B		

CHEMICAL RESISTANCE CHART

		PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS																
CHEMICALS AND FORMULA	CONCENTRATION	ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Lemon Oil				C		250	300			140	100	200							C	C			C	B	A	A	A	A		
Ligroin									100	C	70	100																	
Lime Slurry CaO								100	100	160	100				A	A					A				A		A	A		
Lime Sulfur (CaS)x				73	140			210	C	160	100	185			C	C	C	C	A	A	A		A		A		A	A		
Linoleic Acid CH3(CH2)4HC:CHCH2CH: CH(CH2)7COOH					140	250	300	C	B to 70	C		140		C	C	C	C	C	C	C	C		C	C	B	B	A	A		A
Linoleic Oil					140	230	300					70																		
Linseed Oil		100	185	150	140	280	300	B to 70	180	200	70	250	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Liqueurs					140					70	70																			
Lithium Bromide LiBr					140	225	300		140			200																		
Lithium Chloride LiCl						250		100	70			140			B	B	B		B	B	C		B		A		A	A		
Lithium Hydroxide LiOH								100	70			140			C	C	C	C	A	A			A		A		A	B		
Lubricating Oil (ASTM #1)			73	C	140	280	350	C	180	C	70	150	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Lubricating Oil (ASTM #2)			73	C	140	280	350	C	180	C	70	150	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Lubricating Oil (ASTM #3)			73	C	140	280	350	C	180	C	70	150	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	
Ludox SiO2															C	C	C	C	A	A	A		A		A		A	A		
Magnesium Carbonate MgCO2					140	280	225	170	140	140	140	210			B	B			B	B	B		B	A	A	A	A	A		
Magnesium Chloride MgCl2	Sat'd		185	180	140	280	400	170	180	200	160	170		A	A	A	B	B	C	C	C		C	C	C	C	B	A		A
Magnesium Citrate MgHC6H5O7•5H2O					140	250	300	175	180			225																		
Magnesium Fluoride MgF2								140				200								C			C		B					
Magnesium Hydroxide Mg(OH)2	Sat'd		185	180	140	280	300	170	180	200	160	225		B	C	C	B	B	A	A	A		A	A	A	A	A	A	A	A
Magnesium Nitrate Mg(NO3)2•2H2O			185	180	140	280	300	140	70	140	160	225		A	C	C					B			A	A	A	A	B		
Magnesium Oxide MgO								140	140		160				A	A				A			A				A		
Magnesium Sulfate MgSO4•7H2O			185	180	140	280	300	175	180	140	160	200		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Maleic Acid HOOCCH:CHCOOH	Sat'd		185	180	140	250	250	70	C		C	200		B	C	C	B	C	C	C	C		C	B	A	B	A	B		A
Malic Acid COOHCH2CH(OH) COOH			185	150	140	250	250	C	100	70	70	200		A	B	B			C	C	C		C	A	A	A	A	A		
Manganese Sulfate MnSO4•4H2O				150	140	250	300	175	140	180	160	225			A	A	A		C	C	B		C		A		A	A		
Mercuric Chloride HgCl2			140	180	140	250	300	210	140	140	140	185	C	C	C	C	C	C	C	C	C	C	C	C	C	C	B	C		A
Mercuric Cyanide Hg(CN)2	Sat'd				140	250	300	70	70	140	70	70		C	C	C	C	C	C	C	C		C		A		A	C		
Mercuric Sulfate HgSO4	Sat'd				140	230	300	70	70			70		C	C	C	C	C												
Mercurous Nitrate HgNO3•2H2O	Sat'd				140	230	300	70	C		C	70		C	C	C	C	C	C	C	C		C	A	A	A	A	C		
Mercury Hg			185	150	140	275	300	210	140	140	140	185		C	C	C	C	C	A	A	A		A	A	A	A	A	B		A
Methane CH4		C			140	275	300	C	180	70	70	185	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

CHEMICAL RESISTANCE CHART

		PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS																
CHEMICALS AND FORMULA	CONCENTRATION	ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Methanol (Methyl Alcohol) CH3OH		C	C	180	140	280	300	140	140	140	140	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Methoxyethyl Oleate CH3OCH2CH2 (OOCC17H33)2					73																									
Methyl Acetate CH3CO2CH3						100	300	B to 70	C	C	C	C			B	B			B	B	B		B	B	A		A	A		A
Methyl Acetone C3H6O						C		70	C	C		C		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	
Methyl Acrylate CH2:CHOOCH3	Tech. Pure					100	300	B to 70	C	C	C	C							C						A		A	A		
Methyl Amine CH3NH2			C	C	C	C	300	70			70	100			C	C			A	A	B		A		A		A	C		
Methyl Bromide CH3Br					C	280	300	C	70	C	C	185			C	C	B		C	C	B				B		B	B		
Methyl Cellosolve HOCH2CH2OOH3					C	280		70	C	70	70	C			A	A	B		B	B	B			A	A	A	A	A	A	
Methyl Chloride CH3Cl	Dry	C			C	280	250	C	C	C	C	70	C		A	A	C	C	A	A	A	A	A	A	A	A	A	A	A	A
Methyl Chloroform CH3CCl		C	C			125	200	C	C	C	C	70							A	A			A		A		A			
Methyl Ethyl Keytone (MEK) CH3COC2H5		C	C	C	C	C	200	70	C	C	C	C		A	A	A	A	A	A	A	A		A	A	A	A	A	A	A	A
Methyl Formate HCOOCH3								100	C	C	70	C			A	A	A		A	A	C		A	A	A	A	A	A		A
Methyl Isobutyl Carbinol (CH3)2CHCH2CH (CH3)OH							200	70	70	70	70	70																		
Methol Isobutyl Keytone (CH3)2CHCH2COCH3		C	C	C	C	C	200	70	C	C	C	C							A						A	A	A	A	A	
Methyl Isopropyl Keytone CH3COCH(CH3)2						C	150	C	C	C	C	C																		
Methyl Methacrylate CH2:C(CH3)COOH3					73	125	150	C	C	70	C	C									C									
Methyl Sulfate (CH3)2SO4					73	280	70																							
Methylene Bromide CH2Br2					C	175	250	C	C	C	C	70																		
Methylene Chloride CH2Cl2					C	C	250	C	C	C	C	70			B	B	B		B	B	B				A	A	A	A		A
Methylene Chlorobromide CH2ClBr					C			C	C	C	C	C							A	A					A		A			
Methylene Iodide CH2I2					C	200	250					250																		
Methylsulfuric Acid CH3HSO4					140	125																								
Milk			70	170		225	400	250	180	200	160	300	C	A	B	B	B	B	C	C	C		C	C	A	A	A	A		
Mineral Oil		70	185	120	140	280	300	C	140	B to 70	70	300	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Molasses				73	140	150	300	100	150	150	150	185		A	A	A	A	A	A	A	A		A	A	A	A	A	A		A
Monochloroacetic Acid CH7ClCOOH	50%		73	73	140	150	200	C	70	C	C	70		C	C	C	C	C	C	C	C		C	C	C	C	B	B		
Monochlorobenzene C6H5Cl	Tech. Pure			73		170	200	C	C	C	C	70			A	A			A	A	A	A	A	A	A	A	A	A	A	
Monoethanolamine HOCH2CH2NH2					C	C	100	70	70	C	C	185					C		B	B	B		B		A		A	B		
Motor Oil			185	73	140		350	C	180			250	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	
Morpholine C4H8ONH						75	200	70	C	C	C	C			B	B			B	B	B		B	B	B	B	B	B		
Naphtha		B to 70	73	73	140	280	200	C	140	C	C	150	A		A	A	B		A	A	A	A	A	A	A	A	A	A	A	A
Naphthalene C10H8		B to 70			C	200	250	C	C	C	C	170	A		A	A	B		A	A	A	A		A	A	A	A	A	A	A

CHEMICAL RESISTANCE CHART

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS																
		ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Natural Gas				73	140	280	300	C	140	140	140	185	A	A	A	A	A	A	A	A	A	A		A	A	A	A	A	A	A
Nickel Acetate Ni(OOCH3)2•4H2O					73	250	300	70	70	C		C	C																	
Nickel Ammonium Sulfate NiSO4•(NH4)2SO4•6H2O							250		140	200	160		C		C	C	C	C	C	C	C				A		A	C		
Nickel Chloride NiCl2	Sat'd		185	180	140	280	406	210	180	200	160	210			C	C	B		C	C	C				A		A	C		A
Nickel Nitrate Ni(NO3)2•6H2O	Sat'd				140	280	400	210	180			250	C		C	C			C	C	C			A	A	A	A	C		
Nickel Sulfate NiSO4	Sat'd		185	180	140	280	400	210		200	160	300		A	C	C	B		C	C	C									A
Nicotine C10H14N2					140	70			C	70	C													B	A		A	B		
Nicotinic Acid CsH4N-COOH					140	250		70			140			A	B	B			C	C	C			B	B	B	B	B		
Nitric Acid HNO3	10%		185	180	140	175	250	70	C	100	C	185	C	C	C	C	C	C	C	C	C	C		B	A	A	A	C		
Nitric Acid HNO3	30%	C	180	120	140	125	250	70	C	100	C	160	C	C	C	C	C	C	C	C	C		B	A		A				
Nitric Acid HNO3	40%	C	100	73	100	125	250	C	C	70	C	140	C	C	C	C	C	C	C	C	C		B	A		A				
Nitric Acid HNO3	50%	C	73	100	100	125	250	C	C	70	C	185	C	C	C	C	C	C	C	C	C	C		B	A		A			
Nitric Acid HNO3	70%	C	73	C	73	C	250	C	C	C	C	100	B	C	C	C	C	C	C	C	C	C		C	A		A			
Nitric Acid HNO3	100%	C		C	C	C	70	C	C	C	C	C	B	C	C	C	C	C	C	C	C	C	C	C	A		A	C		
Nitrobenzene C6H5NO2				73	C	73	400	C		C	C	70			B	B			A	A	A				A		A	A		A
Nitroethane CH3CH2NO2	Tech. Pure					70			C		C	C								A										
Nitrogen Gas N2						275	300		140	100	140	185	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	
Nitroglycerin CH2NO3CH-NO3 CH2NO3					C	125	70								B	B				B	B				A		A	B		
Nitroglycol					C					70	70																			
Nitromethane CH3NO2	Tech. Pure					120		70	C		C														A					
Nitrous Acid HNO2	10%				73	230	400		C			100	C	C	C	C	C	C	C	C	C			B	B	B	B	C		
Nitrous Oxide N2O				73	73	C	400		C	B to 140	C	70			B	B			C	B	B				A		A	C		A
n-Octane CH8H18						275	400	C	B to 70			70	A	A	A	A	A	A	A	A	A	A		A	A	A	A	A	A	A
Oleic Acid CH3(CH2)7CH:CH (CH2)7COOH			185	150	140	250	250	B to 70	100	70	B to 70	185		A	B	B	A		B	B	C			B	A	A	A	A		A
Oleum xH2SO4•ySO3				C	C	C	150	100	C	C	C	70			C	C	C	C	C	C	C				A		A	C		A
Olive Oil						250	350		140	B to 100	140	150		A	A	A	A	A	A	A	A	A		A	A	A	A	A	A	
Oxalic Acid HOOCCOOH•2H2O	50%		185	180	140	125	300	150	C		100	100	C		C	C	C		C	C	C	C	C	B	A	A	A	A		A
Oxygen (Gas) O2			185	150	140	280	406	210	B to 70	140	140	185	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Ozone O3					140	225	300	210	C	140	C	185	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Palm Oil						200	200	C	140	C		70			C	C			C	C	C		C		A		A	A		
Palmitic Acid CH3(CH2)14COOH	10%		73	180	140	250	300	70	100	70	C	185		A	B	B	B	A	B	B	B		B	B	B	A	A	A	A		
Palmitic Acid CH3(CH2)14COOH	70%		73	180	73	250	300		100	C	C	185		A	B	B	B	A	B	B	B		B	B	B	A	A	A	A		

CHEMICAL RESISTANCE CHART

		PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS																
CHEMICALS AND FORMULA	CONCENTRATION	ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Paraffin C36H74		B to 70			140	250	250	C	100		140	300		A	A	A	A		B	A	A	B	B	A	A	A	A	A	A	A
Peanut Oil						250	250		100			150			A	A			A	A			A		A		A			
n-Pentane CH3(CH2)3CH3		C					100	C	100		70	100	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Peracetic Acid CH-3COOOH	40%				73																									
Perchloric Acid HClO4	10%		140	73	73	200	250	70	C	70	70	70							C						A		A	A		
Perchloric Acid HClO4	70%		185	73		125		70	C	C	C	185							C						B		B	A		
Perchloroethylene CI2C:CCI2						275	200	C	C	C	C	200			B	B			B	B	B		B	A	A	A	A	A		A
Perphosphate			170	170	140		250	70	70			70																		
Phenol C6H5OH		C	73	73	73	125		70	C	C	C	200			A	A	C		C	C	C		C	A	A	A	A	A		A
Phenylhydrazine C6H5NHNH2					C	125	B to 70	C	C	C		C																		
Phospate Esters									C		C	100			C	C			C	C			C		A		A	A		
Phosphoric Acid H3PO4	10%		210	180	140	275	300	140	70	200	140	200	C	C	C	C	C	C	C	C	C	C	C	B	A	A	A	C		
Phosphoric Acid H3PO4	50%		210	180	140	275	300	70	C	200	70	200	C	C	C	C	C	C	C	C	C	C	C	B	A	A	A	C		
Phosphoric Acid H3PO4	85%		73	180	140	275	300	70	C	200	C	200	C	C	C	C	C	C	C	C	C	C	C	B	A	B	A	C		
Phosphoric Anhydride P2O5			73	73	73	200							B								C				A		A			
Phosphorus (Red)					70	75	300																		A		A			
Phosphorus (Yellow)					73		300																							
Phosphorus Pentoxide P2O5			73	73	73	200		140					C				C				B				A		A			
Phosphorus Trichloride PCI3					C	200	300		C	C	C		C												A		A	A		
Photographic Solutions			185	150	140					100	100	185								C					A		A			
Phthalic Acid C6H4(COOH)2					73	200			C	140	C	140		A	A	A			B	B	C		B		A	A	A	B		A
Picric Acid C6H2(NO2)3OH	10%	C	140	170	170	73		140	C	70	70	140	C	C	C	C	C	C	C	C	C	C	C	B	A		A	C		A
Pine Oil									70		C	70			C	C	B		B	B	B		B	A	A	A	A	A		
Plating Solutions (Brass)			185	180	140	200	300	70			100	70																		
Plating Solutions (Cadmium)			185	180	140	200	300	70			100	70																		
Plating Solutions (Chrome)			210	180	140	200	300				160														A		A			
Platings Solutions (Copper)			210	180	140	200	300	70			160	70																		
Platings Solutions (Gold)			185	180	140		300	70			125	70																		
Platings Solutions (Lead)			210	180	140	200	300	70	70		70	70																		
Platings Solutions (Nickel)			210	180	140	200	300	70				70		C		C		C							A		A*			
Platings Solutions (Rhodium)			185	180	140	200	300					70																		
Platings Solutions (Silver)			185	180	140	200	300	70			70	70	A												A		A			

Note: A* rating for Electroless Plating only.

CHEMICAL RESISTANCE CHART

		PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS																	
CHEMICALS AND FORMULA	CONCENTRATION	ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Platings Solutions (Tin)			210	180	140	200	300	100				140															A	A		
Platings Solutions (Zinc)			185	180	140	200	300	70				70									B									
Polysulfide Liquor							300	70	70	70	70	100		C	C	C	C	C	B	B			B		B		B	B		
Polyvinyl Acetate						275	350	70	70	70	70	70			B	B	B		A	A	C		A	B	B	B	B	B		
Potash KOH					140	280	400	140	180	180	70	200		B	B	B	B	B	A	A	A	A	A	A	A	A	A	A	A	
Potassium Alum ALK(SO4)212H2O "					140	280	400	210	180	200	160	200																		
Potassium Aluminum Sulphate					140	280	400	210	180	200	160	200	B	B		B		C			C			B	A		A	A		
Potassium Amyl Xanthate					73																									
Potassium Bicarbonate KHCO3	Sat'd		73	170	140	200	400	170	70	200	160	200	A								A				A		A			
Potassium Bichromate K2Cr2O7	Sat'd				140	230	400	170	180			300	B	A		A		B			B			B	A		A			
Potassium Bisulfate KHSO4					140	275	400	170	180	140	140	200			B	B	B		C	C	C	C	C		A		A	C		
Potassium Borate K2B4O75H2O "					140	275	400	170	180	140	140	200								A	A		A		A		A			
Potassium Bromate KBrO3				180	140	275	400		180	140	140	250							C	A	A		A		A		A			
Potassium Bromide KBr				180	140	280	400	170	180	200	160	200			B	B	B		C	C	C				A		A	A		
Potassium Carbonate K2CO3		70		180	140	280	400	170	180	200	160	200		B	B	B	B	B	A	A	A	A	A	A	A	A	A	A	A	
Potassium Chlorate KClO3 (Aqueous)				180	140	200	400	140	B to 70	140	100	140		B	B	B			A	A	A	A		A	A	A	A	A	A	
Potassium Chloride KCl			185	180	140	280	400	210	180	200	160	200		B	A	A	B	B	B	B	C	B	B	B	A	A	A	A		A
Potassium Chromate K2CrO4					140	280	400	170	140	70	70	200			A	A	B		B	B	B		B		A	A	A	A		
Potassium Cyanide KCN			185		140	280	400	140	180	200	160	185	C	C	C	C	C	C	B	B	B	B		A	A	A	A	A		A
Potassium Dichromate K2Cr2O7	Sat'd		185		140	280	400	170	180	200		300			B	B	C		B	B	C			A	A	A	A	A		
Potassium Ethyl Xanthate KS2COC2H5					73																									
Potassium Ferricyanide K3Fe(CN)6					140	280	400	140	70	200	150	140	C		C	C			B	B	C				A		A	A		
Potassium Ferrocyanide K4Fe(CN)63H2O "					140	280	400	140	70	200	150	140	C	C	B	B	C	C	C	C	C			B	A		A	A		
Potassium Fluoride KF					140	275	400	140	180			250													A		A	A		
Potassium Hydroxide KOH	25%		185	150	140	150	400	210	B to 70	140	160	140	C		C	C	C		B	B	B	B		A	A	A	A	A		
Potassium Hypochlorite KClO		C		C		200	400	70	C	70		70			C	C					C				A		A	C		
Potassium Iodide KI				73		250	400	140	100	140	160	180			B	B					B	B			A		A	A		
Potassium Nitrate KNO3					140	280	400	210	180	140	140	250		A	A	A	B	B	B	B	B	B		A	A	A	A	A	A	A
Potassium Perborate			170	170	140	275	400		70		70																			
Potassium Perchlorate KClO4					140	200	200	140	C	150		150																		
Potassium Permanganate KMnO4	10%			150	140	250	400	210	C	100	100	140			B	B			A	A	A			A	A	A	A	A	A	
Potassium Permanganate KMnO4	25%			150	73	250	400	140	C	100	100	140			B	B			A	A	A			A	A	A	A	A	A	

CHEMICAL RESISTANCE CHART

		PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS																	
CHEMICALS AND FORMULA	CONCENTRATION	ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Potassium Persulfate K2S2O8					140	125	400	210	C	200	140	200																		
Potassium Sulfate K2SO4				180	140	280	200	210	140	140	140	250		A	A	A	B	B	A	A	A	A	B	A	A	A	A	A	A	A
Potassium Sulfide K2S						275	300		100		70	100		C	C	C	C	C	C	C	C	B		B	B	B	B	C		A
Potassium Sulfite K2SO32H2O "							300	140	70		70	200			B	B	B		C	C	C				A		A	B		
Potassium Tripolyphosphate K5P3O10							300		70		70	100	C				B		A		A	A			A		A	A		
Propane C3H8			73		140	280	300	C	70	B to 70	70	70	A	A	A	A	A	A	A	A	A	A		A	A	A	A	A	A	A
Propargyl Alcohol HC:CCH2OH				140	100	140		140		140	C	140																		
Propionic Acid CH3CH-2CO2H		C							140	70	C			A											A		A			
Propyl Acetate C3H7OOCCH3						100	140	B to 70	C	C	C	C	A					A			A			A	A	A	A	A	A	
Propyl Alcohol CH3CH-2CH2OH		C		140		140	350	140	140	140	140		A	A	A	A	A	A	A	A	A	A		A	A	A	A	A	A	A
n-Propyl Bromide CH3CH2CH2Br							300	B to 70			70	70			B	B	B		B	B	B				A		A	B		
Propylene Dichloride CH3CHCICH2CI					C	200		C	C		C	B to 70									A							A		
Propylene Oxide CH3CHCH2O					C	C	150	70	C	C	C	C									A				A		A			
n-Propyl Nitrate C3H7NO3							200	70	C	C	C	C							A	A			A		A		A			
Pyridine N(CH)4CH				73	C	C		B to 70	C	C	C	C			B	B			B	B	B		B	C	B		A	B		
Pyrogallic Acid C6H3(OH)3					73	150	150		70		70				A	A			A	A	A		A	A	A	A	A	A	A	A
Pyrrole CHNH(CH)2CH								C	C	C	C	C			B	B			B	B	B		B		B		B	B		
Quinone C6H4O2								100		C		C							A	A			A		A		A			
Rosin							200		70	70	70	100			C	C			C	C	C		C	A	A	A	A	A		
Salicylaldehyde C6H4OHCHO					C	125	200	70	70			70																		
Salicylic Acid C6H4(OH)(COOH)					140	200	300	210	C	70	C	185			B	B			C	C	C		C		A		A	B		
Selenic Acid H2SeO4					140	150			70	70	70																			
Silicic Acid SiO2nH2O "					140		400	140	100	140	140	200																		
Silicone Oil			150	150	73	250	350	140	140	140	70	185	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Silver Chloride AgCI														C	C	C	C	C	C	C	C		C	C	C	C	Ato 70	A		
Silver Cyanide AgCN			185		140	280	350	140	C		70	140		C	C	C	C	C	C	C	C		C		Ato 100		Ato 70	A		
Silver Nitrate AgNO3		70	185	180	140	280	350	210	140	200	160	250		C	C	C	C	C	C	C	C		C	B	A		A	C		
Silver Sulfate Ag2SO4		70			140	250	350	170	140			200																		
Soaps		70	185	73	140		400	210	180	140	140	250			B	B	A		B	B	B		B	A	A	A	A	B		A
Sodium Acetate NaC2H3O2	Sat'd		185	180	140	280	400	170	C	70		C			A	A	B		B	B	C		B	B	A		A	A		A
Sodium Alum AlNa(SO4)212H2O "					140	280		170	180	140	140	210	C								C									
Sodium Aluminate Na2Al2O3	Sat'd						300	200	180	140	140	200			C	C	B		B	B	A		B		A		A	A		A

CHEMICAL RESISTANCE CHART

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS																
		ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Sodium Benzoate C6H5COONa			140	170	140	280	300	210	140			200																A		
Sodium Bicarbonate NaHCO3		70	185	180	140	280	400	250	180	200	160	300		A	A	A	B	B	A	A	C		A	A	A	A	A	A	A	A
Sodium Bichromate Na2Cr2O72H2O "	Sat'd		140	140	140	250	400	140	140	70	70	200			C	C								A	A	A	A	A		
Sodium Bisulfate NaHSO4		70		180	140	280		200	180	100	140	250		C	C	C	C	C	C	C	C		C	B	A		A	A		
Sodium Bisulfite NaHSO3			185	180	140	280	400	200	180	200	140	250			B	B			C	C	C		C		A		A	C		A
Sodium Borate (Borax) Na2B4O710H2O "	Sat'd			73			300	140	70	100	100	140			A	A			B	B			B	A	A	A	A	A		
Sodium Bromide NaBr	Sat'd		180	180	140	280	300	210	70		70	250			B	B			C	C	C		C		A		A	A		
Sodium Carbonate Na2CO3		70	185	180	140	280	400	140	140	140	140	300		C	A	A	B	B	A	A	A	A	A		A	A	A	A	B	A
Sodium Chlorate NaClO3	Sat'd			180	73	250	350	B to 140	B to 70		B to 140	100			A	A	C		B	B	B		B	B	A	A	A	C		
Sodium Chloride NaCl			210	180	140	280	350	140	140	100	160	200	B	A	A	A	B	B	B	B	C	A	B	B	B	B	A	A	A	A
Sodium Chlorite NaClO2	25%		73		C	250	200	C	C	140		C																		
Sodium Chromate Na2CrO410H2O "						200		70	70		70	70			A	A			B	B	B		B	A	A	A	A	A		
Sodium Cyanide NaCN			185	180	140	280	350	140	140	140	140	200		C	C	C	C	C	A	A	A	A		A	A	A	A	A		
Sodium Dichromate Na2Cr2O72H2O "	20%		185	180	140	200	300	140	C	200	C	200			C	C	C		B	B	B				A		A	B		
Sodium Ferricyanide Na3Fe(CN)62H2O "	Sat'd		140	140	100	275	350	140	70			140			C	C			C	C					A		A			
Sodium Ferrocyanide Na3Fe(CN)610H2O "	Sat'd		185		140	275	350	140	70			140													A		A	A		
Sodium Fluoride NaF			140	185	140	280	350	140	70	140	70	140			A	A	B		C	C	C				A		A	A		
Sodium Hydroxide NaOH	15%	140	210	180	140	170	400	210	140	200	160	C	C		A		A			A	A		B	A	A	A	A	A	A	A
Sodium Hydroxide NaOH (Caustic Soda)	30%	140	210	180	140	C	350	140	100	140	160	C	C		A		B			B	B		B	A	A	A	A	A		
Sodium Hydroxide NaOH	50%	140	210	180	140	C	350	140	C	140	160	C	C	B	B	C	C	C	B	B	B	B	B	A	A	A	A	A		
Sodium Hydroxide NaOH	70%	70		180	100	C	350	70	C	100	100	C	C	B	C	C	C	C	B	B	B	B	B	A	A	A	A	A		
Sodium Hypochlorite NaOCl5H2O "		C	185	C	73	200	350	70	C	150	C	140	C	C	C	C	C	C	C	C	C	C	C	C	A		A	A		A
Sodium Iodide NaI						275				140	160																			
Sodium Metaphosphate (NaPO3)n				73		280		70	70	70		70			C	C	C		C	C	C				A		A	B		
Sodium Nitrate NaNO3	Sat'd		185	180	140	280	400	210	140	140	140	225		B	A	A	B	B	A	A	A	A	A	A	A	A	A	A	B	A
Sodium Nitrate NaNO2					140	280	400	170	C	140	140	200			A	A			B	B	B				A		A	A		
Sodium Palmitate CH3(CH2)14COONa	5%					250	350																							
Sodium Perborate NaBO23H2O "				73	140		350	70	70	70	70	70			C	C			B	B	B			A	A	A	A	A		A
Sodium Perchlorate NaClO4		170	170		140	250	350		B to 70																					
Sodium Peroxide Na2O2					140	200	250	140	B to 70	200	70	185		B	C	C	C	C	C	C	C			A	A	A	A	A		B
Sodium Phosphate NaH2PO4	Acid			180		280	400	170	140	200	140	200		B	B	B	B	B	B	B	B	A	B	A	A	A	A	B		A
Sodium Phosphate NaH2PO4	Alka-line			180		280	400	170	140	200	140	200		B	B	B	B	B	B	B	B	A	B	A	A	A	A	B		A

CHEMICAL RESISTANCE CHART

		PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS															
CHEMICALS AND FORMULA	CONCENTRATION	ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Sodium Phosphate NaH2PO4	Neutr al			180		280	400	170	140	200	140	200		B	B	B	B	B	B	B	B	A	B	A	A	A	A	B		A
Sodium Silicate 2Na2OSiO2 "				180		280		200	140	200	140	200			C	C	B		A	A	A		A	A	A	A	A	A	A	A
Sodium Sulfate Na2SO4	Sat'd	70	185	150	140	280	400	140	140	140	140	200		A	A	A	B	B	A	A	A	A	A	A	A	A	A	A	A	A
Sodium Sulfide Na2S		70	185	150	140	280	350	140	180	200	140	200		C	C	C	C	C	B	B	C	B	B	A	A	A	A	A		
Sodium Sulfite Na2SO3		70	185	180	140	280	350	140	140	140	140	200			A	A	C		B	B	B		B	B	A	A	A	C		A
Sodium Thiosulphate Na2S2O35H2O "				150	140	280	350	200	140	200	160	200	A		B	B	C		C	C	C		C		A		A	A		
Sour Crude Oil					140	280		C	C	70	C	200			C				A	A	A		B	A	A	A	A	A	A	A
Soybean Oil						250	400	C	140	200	70	250			A	A	B		A	A	B	A	A	A	A	A	A	A	A	
Stannic Chloride SnCl4			185		140	280	350	100	140	70	C	200		C	C	C	C	C	C	C	C	C	C	C	C	C	A	C	C	
Stannic Chloride SnCl2	15%		185		140	280	350	70	140	200	160	200			C	C	C	C	C	C	C	C	C		A		A	C		
Starch					140	200	300	170	180	200	160	200			B	B	B	B	B	B	B		B	A	A	A	A	A		
Steam (Low Pressure)						280	400	C	C	C	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Steam (Medium Pressure)							400	C	C	C	C	C	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B		A
Steam (High Pressure)							C	C	C	C	C	C	C	C	C	C	C	C	C	B	A	C	B	A	A	A	A	C		A
Stearic Acid CH3(CH2)16COOH			185	73	140	275	350	C	140	70	70	100		A	A	A	C	B	C	C	C	B	C	A	A	A	A	A		A
Stoddard's Solvent						280		C	140	C	C	185	A		A	A			A	A	A		A		A	A	A	A	A	A
Styrene (C6H5CHCH2)n						180	350	C	C	C	C	100			B	B	B		B	B	B		B		A		A	A		A
Succinic Acid CO2H(CH2)2CO2H				150	140	150	200	70	70			70			A	A			A	A	A		A	A	A	A	A	A	A	A
Sugar C6H12O6						275	350	140	100	140	140	200			C	C				B	C		B	A	A	A	A	A		
Sulfamic Acid HSO3NH2	20%			180	140	C		C	C	70	70	C		A	B	B	B		C	C	C		C		A		A	B		
Sulfate Liquors (Oil)				73			200	70	70			70		C	C	C	C	C	B	A			A		A		A	A		
Sulfite Liquors	6%				140		350	140	70	70	70	140									C	B			A		A			
Sulfur S				C	140	250	350		C	70	70	250	C	C	C	C	C	C	B	B	C	B	B	B	A		A	A		A
Sulfur Chloride S2Cl2				C		73	350	C	C	70	C	70	C	C	C	C	C	C	C	C	C	C	C	C	C	C	B	C	C	
Sulfur Dioxide SO2	Dry		C	73	140	175	350	70	C	200	C	100	A	A	A	B	A	A	A	A	A		A	A	A	A	A	A	A	A
Sulfur Dioxide SO2	Wet		C	73	73	150		140	C	200		140	B	C	C	B	B	C						C	A	C	A	A		A
Sulfur Trioxide SO3					140	C		70	C	C	C	140		C	C			C						C	B	B	A	A		A
Sulfuric Acid H2SO4	Up to 30%	100	210	180	140	250	250	140	C	100	100	200		C	C	C	C	C	C	C	C	C	C	C	A	B	A	A	C	A
Sulfuric Acid H2SO4	50%	70	210	150	140	250	250	140	140	150	C	200		C	C	C	C	C	C	C	C	C	C	C	A	C	A	A	C	A
Sulfuric Acid H2SO4	60%	C	210	150	140	250	250	140	C	150	C	250	C	C	C	C	C	C	C	C	C	C	C	C	B	B	A	B	C	A
Sulfuric Acid H2SO4	70%	C	210	120	140	200	200	140	C	150	C	250	C	C	C	C	C	C	C	C	C	C	C	C	B	C	A	C	C	A
Sulfuric Acid H2SO4	80%	C	210	73	140	200	200	70	C	150	C	150	C	C	C	C	C	C	C	C	C	C	C	C	C	C	A	C	C	A

CHEMICAL RESISTANCE CHART

		PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS																	
CHEMICALS AND FORMULA	CONCENTRATION	ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Sulfuric Acid H2SO4	90%	C	73	C	100	200	200	C	C	70	C	150	C	C	C	C	C	C	C	C	C	C	C	C	C	C	A	C	C	A
Sulfuric Acid H2SO4	93%	C	73	C	100	200	B to 200	C	C	70	C	150	C	C	C	C	C	C	C	C	C	C	C	C	C	C	B	C	C	A
Sulfuric Acid H2SO4	94%	C	73	C	100	150	B to 200	C	C	C	C	150	C	C	C	C	C	C	C	C	C	C	C	C	C	C	B	C	C	A
Sulfuric Acid H2SO4	95%	C	73	C	100	150	B to 200	C	C	C	C	150	C	C	C	C	C	C	C	C	C	C	C	C	C	C	B	C	C	A
Sulfuric Acid H2SO4	96%	C	73	C	100	150	B to 200	C	C	C	C	140	C	C	C	C	C	C	C	C	C	C	C	C	C	C	B	C	C	B
Sulfuric Acid H2SO4	98%	C	73	C	C	150	B to 200	C	C	C	C	70	C	C	C	C	C	C	C	C	C	C	C	C	C	C	B	C	C	B
Sulfuric Acid H2SO4	100%	C	C	C	C	C	B to 200	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	B	C	B	C	C	
Sulfurous Acid H2SO3	Sat'd	C		140	100	210	350	75		150	C	100		C	C	C	C	C	C	C	C	C	C	B	A	A	A	A	C	A
Tall Oil					140	280	250	C	140	C	B to 70	70			B	B	B		B	B	B		B	A	A	A	A	B		A
Tannic Acid C76H52O46	10%	C	185	180	140	225	250	70	100	100	100	100			A	A			B	B	C	B	B	B	A	A	A	A		A
Tanning Liquors			185		140				70	70	70	200	A		A	A			B						A		A			
Tar						250	250	C	C	70	70	185	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A		A
Tartaric Acid HOOC(CHOH)2COOH				150	140	250	250	C	70	200	70	70		B	A	A	C	C	C	C	C	C	C	A	A	A	A	A		A
Terpineol C10H17OH					C			C	70	C	C																			
Tetrachloroethane CHCl2CHCl2						250	400	C	C	C	C	70													A		A			
Tetrachloroethylene Cl2C:CCl2		C				275	350	C	C	C	C	70																		
Tetraethyl Lead Pb(C2H5)4					73	280	350	C	70	C		70			A	A				B	B		A				A	A		
Tetrahydrofuran C4H8O			C	C	C	C		C	C	C	C	C																		
Tetralin C10H12							200	C	C		C	C																		
Tetra Sodium Pyrophos-phate N94PzO710H2O "					140																									
Thionyl Chloride SOCl2					C				C		C																			
Thread Cutting Oils					73	200	350	C	70			70	A		A				A	A	A			A	A	A	A		A	A
Titanium Tetrachloride TiCl4					C	150		C		C	C	185			C	C					C				B		B	B		
Toluene (Toluol) CH3C6H5		C	C	C	C	175	200	C		C	C	70	A	A	A	A	A	A	A	A	A	A		A	A	A	A	A	A	A
Tomato Juice				180		200	350	200	C	C	70	200	A		B				C	C	B				A	A	A	A		
Transformer Oil				120	140		300	C	140		C	140	A		A					A	A				A	A	A	A		A
Transformer Oil DTE/30							300	C	140	C	C		A		A					A	A				A	A	A	A		A
Tributyl Citrate					73																									
Tributyl Phosphate (C4H9)3PO4					C	73	300	70	C	C	C	C			B	B	B		A	A	A			B	A		A	A		
Trichloroacetic Acid CCl3COOH				150	140	125	200	70	B to 70	70	70	C	C		B	C			C	C	C			C	B		B			
Trichloroethylene CHCl:CCl2		C	C	C	C	280	200	C	C	C	C	185	A	A	A	A	A	A	B	B	B			A	A	A	A	A	A	A
Triethanolamine (HOCH2CH2)3N		70			73	125		70	70	150	70	C			C	C			C	C	C	C		C	A		A	A		

CHEMICAL RESISTANCE CHART

		PLASTICS AND ELASTOMERS AT MAXIMUM TEMPERATURE (°F)											METALS															
CHEMICALS AND FORMULA	CONCENTRATION	ABS	CPVC	PP	PVC	PVDF	TEFLON	EPDM	BUNA-N	HYPALON	NEOPRENE	FLUOROCARBON	ALUMINUM	COPPER	BRONZE (85% Cu)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES S.S.	316 S.S.	17-4 PH	ALLOY 20	MONEL	STELLITE	HASTELLOY C
Triethylamine (C2H5)3N					140	125			140		70	200			A	A											A		
Trimethylpropane (CH2OH)3C3H5					73				180	200	160	300																	
Trisodium Phosphate NaPO412H2O "		70	185	185	140	280	350	70	70	185	70	185			C	C			B	B		A			A	A	A	A		
Tung Oil								C	100	100	100	100			B	B	B		B	B	B			B	A	A	A	A		A
Turpentine			73	C	140	280		C	70	C	C	150	A	A	A	A	A	A	A	A	A	A		A	A	A	A	A	A	A
Urea CO(NH2)2			185	180	140	250		210	140	140	140	185		C		B	B			C	C	C				A	A	B	C	
Urine				180	140		400	210	140	140	140	70							C	C	C			A	A	A	A	A		
Varnish						250	350	C	70		C	70		A	A	A	B	B	C	C	C			B	A	A	A	A		A
Vaseline (Petroleum Jelly)				150	C		300	C	140	70	140	70							A	A	A			A	A	A	A	A	A	A
Vegetable Oil			185	100	70	275	300	C	70	70	70	200	A		A	A				A	A			A	A	A	A	A	A	
Vinegar		73	150	140	140	225	300	140	C	200	70	C	C	B	C	C	C	C	C	C	C			A	A	A	A	A		A
Vinyl Acetate CH3COOCH:CH2				C	C	250	350	70	70	C	C	C			B	B			B	B	B				A		A	B		
Water, Acid Mine H2O			185		140	230	400	200	180	180	160		C	C	C	C	C	C	C	C	C	C	C	A	A	A	A	B	B	B
Water, Deionized H2O		70	210	180	140	280	400	200	70		160		A	A	B	B	C	C	C	C	C		C	B	A	A	A	A		A
Water, Distilled H2O		70	210	180	140	280	400	250	180	200	160		A	A	A	A	B	B	C	C	C	B	C	A	A	A	A	A	B	A
Water, Potable H2O		70	210	180	140	280	400	250	180	200	160		B	A	A	A	A	A	B	B	B	A	B	A	A	A	A	A	A	A
Water, Salt H2O		70	210	180	140	280	400	250	180	200	160		C	B	B	B	C	C	C	C	C	B	C	B	A	A	A	A	B	A
Water, Sea H2O		70	210	73	140	280	400	250	180	200	160		C	B	B	B	C	C	C	C	C	B	C	B	B	A	A	A	C	A
Water, Soft H2O		70				200	400	250	180	200	160		A	A	A	A	A	B	C	C	B	B	C	A	A	A	A	A	A	A
Water, Waste H2O		70	185	180	140	230	400	200				70	B	B	B	B	B	B	B	B	B	B	B	B	A		A	A		A
Whiskey			185	150	140	200	350	200	140	140	140	140		A	C	C	B		C	C	C		C	B	A		A	A		A
White Liquor			185		140	230			140	140	140				C	C	C		C	C	C		C		A		A	A		
Wine			185	150	140	200	350	170	140	140	140	140			C	C			C	C	C		C	B	A		A	A		
Xylene (Xylol) C6H4(CH3)2		C	C	C	C	200	350	C	C	C	C	150	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Zinc Acetate Zn(C2H3O2)22H2O "						250		180	70	70	160	70			C	C	C	C	C	C	C		C		A		A	A		
Zinc Carbonate ZnCO3									100	100					B	B									B		A	B		
Zinc Chloride ZnCl2			185	180	140	280	400	180	70	200	160	200			C	C	C		C	C	C		C	C	B	B	A	A		
Zinc Nitrate Zn(NO3)26H2O "					140	280		180	140	200		200													A	A	A			
Zinc Sulfate Zn-SO47H2O "			185	180	140	280	400	180	140	200	140	200		A	C	C	B		C	C	C	B	C	A	A	A	A	A		A
Trichloroacetic Acid CCl3COOH				150	140	125	200	70	B to 70	70	70	C	C		B	C			C	C	C			C	B		B			
Trichloroethylene CHCI:CCl2		C	C	C	C	280	200	C	C	C	C	185	A	A	A	A	A	A	B	B	B			A	A	A	A	A	A	A
Triethanolamine (HOCH2CH2)3N		70			73	125		70	70	150	70	C			C	C			C	C	C	C		C	A		A	A		

To the best of our knowledge the information contained herein is accurate. However, neither Fabco nor any of its affiliates assumes any liability in whatsoever for the accuracy or completeness of the information contained herein. Final determination of the suitability of any information or material for the use contemplated, the manner of use, andwhether there is any infringement of patents is the sole responsibility of the user.

Glossary of Terms

Adhesive – a substance capable of holding materials together by surface attachment.
Adhesive solvent – an adhesive having a volatile organic liquid as a vehicle. See Solvent Cement.
Aging – (1) The effect on materials of exposure to an environment for an interval of time. (2) The process of exposing materials to an environment for an interval of time.
Antioxidant – a compounding ingredient added to a plastic composition to retard possible degradation from contact with oxygen (air), particularly in processing or exposure to high temperatures.
Artificial weathering – the exposure of plastics to cystic laboratory conditions involving changes in temperature, relative humidity, and ultraviolet radiant energy, with or without direct water spray, in an attempt to produce changes in the materials similar to those observed after long-term continuous outdoor exposure. Note: The laboratory exposure conditions are usually intensified beyond those encountered in actual outdoor exposure in an attempt to achieve an accelerated effect. This definition does not involve exposure to special conditions such as ozone, salt spray, industrial gases, etc.
Bell end – the enlarged portion of a pipe that resembles the socket portion of a fitting and that is intended to be used to make a joint by inserting a piece of pipe into it. Joining may be accomplished by solvent cements, adhesives, or mechanical techniques.
Beam loading – the application of a load to a pipe between two points of support, usually expressed in pounds and the distance between the centers of the supports.
Burst strength – the internal pressure required to break a pipe or fitting. This pressure will vary with the rate of build-up of the pressure and the time during which the pressure is held.
Cement – see adhesive and solvent, cement.
Chemical resistance – (1) The effect of specific chemicals on the properties of plastic piping with respect to concentrations, temperature and time of exposure. (2) The ability of a specific plastic pipe to render service for a useful period in the transport of a specific chemical at a specified concentration and temperature.
Cleaner – medium strength organic solvent such as methyl ethyl katone to remove foreign matter from pipe and fitting joint surfaces.
Compound – the intimate admixture of a polymer or polymers with other ingredients such as fillers, softeners, plasticizers, catalysts, pigments, dyes, curing agents, stabilizers, antioxidants, etc.
Copolymer – see Polymer.
Creep – the time-dependent part of strain resulting from stress, that is, the dimensional change caused by the application of load over and above the elastic formation and with respect to time.
Deflection Temperature – the temperature at which a specimen will deflect a given distance at a given load under a prescribed conditions of test. See ASTM D648. Formerly called heat distortion.
Deterioration – a permanent change in the physical properties of a plastic evidenced by impairment of these properties. Note a. – Burst strength, fiber stress, hoop stress, hydrostatic design stress, long-term hydrostataic strength, hydrostatic strength (quick), long-term burst, ISO equation, pressure, pressure rating, quick burst, service factor, strength, stress and sustained pressure test are related terms.
Elasticity – that property of plastics materials by virtue of which they tend to recover their original size and shape after deformation. Note – if the strain is proportional to the applied stress, the material is said to exhibit Hookean or ideal elasticity.
Elastomer – a material which at room temperature can be stretched repeatedly to at least twice its original length and, upon immediate release of the stress, will return with force to its approximate original length.
Elevated temperature testing – tests on plastic pipe above 23° (73°F).
Environmental stress cracking – cracks that develop when the material is subjected to stress in the presence of specific chemicals.
Extrusion – a method whereby heated or unheated plastic forced through a shaping orifice becomes one continuously formed piece. Note – this method is commonly used to manufacture thermoplastic pipe.
Failure, adhesive – rupture of an adhesive bond, such that the plane of separation appears to be at the adhesive-adherend interface.
Fiber stress – the unit stress, usually in pounds per square inch (psi), in a piece of material that is subjected to an external load.
Filler – a relatively inert material added to a plastic to modify its strength, permeance, working properties, or other qualities, or to lower costs.
Fungi resistances – the ability of plastic pipe to withstand fungi growth and/or their metabolic products under normal conditions of service or laboratory tests simulating such conditions.
Heat joining – making a pipe joint by heating the edges of the parts to be joined so that they fuse and become essentially one pipe with or without the addition of additional material.
Hoop stress – the tensile stress, usually in pounds per square inch (psi), in the circumferential orientation in the wall of the pipe when the pipe contains a gas or liquid under pressure.
Hydrostatic design stress – the estimated maximum tensile stress in the wall of the pipe in the circumferential orientation due to internal hydrostatic pressure that can be applied continuously with a high degree of certainty that failure of the pipe will not occur.
Hydrostatic strength (quick) – the hoop stress calculated by means of the ISO equation at which the pipe breaks due to an internal pressure build-up, usually within 60 to 90 seconds.
Long-term burst – the internal pressure at which a pipe or fitting will break due to a constant internal pressure held for 100,000 hours (11.43 years).
Impact, Izod – a specific type of impact test made with a pendulum type machine. The specimens are molded or extruded with machined notch in the center. See ASTM D256.
ISO equation – an equation showing the inter-relations between stress, pressure and dimensions in pipe, namely:

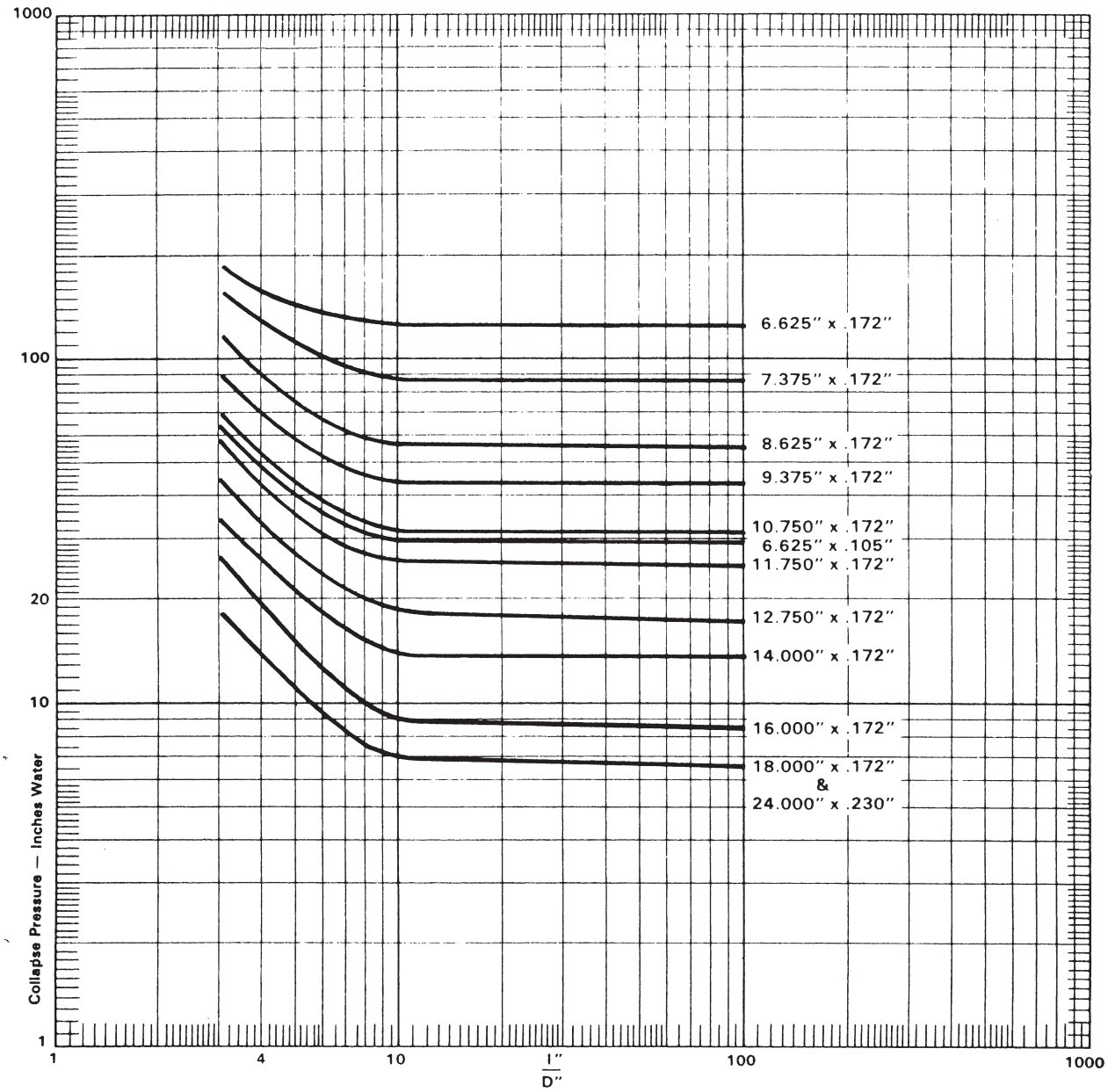
$$S = \frac{P\,(ID + t)}{2t} \text{ or } S = \frac{P\,(OD - t)}{2t}$$

Where:
S = stress
P = pressure
ID = average inside diameter
OD = average outside diameter
t = minimum wall thickness (Note a)
Reference: ISO R161–1960 Pipes of Plastics Materials for the Transport of Fluids (Outside Diameters and Nominal Pressures) Part I, Metric Series.
Joint – the location at which two pieces of pipe or a pipe and a fitting are connected together. The joint may be made by an adhesive, a solvent-cement or a mechanical device such as threads or a ring seal.
Long-term hydrostatic strength – the estimated tensile stress in the wall of the pipe in the circumferential orientation (hoop stress) that when applied continuously will cause failure of the pipe at 100,000 hours (11.43 years). These strengths are usually obtained by extrapolation of log-log regression equations or plots.
Molding, injection – a method of forming plastic objects from a granular or powdered plastics by the fusing of plastic in a chamber with heat and pressure and the forcing part of mass into a cooler chamber where it solidifies. Note: this method is commonly used to manufacture thermoplastic fittings.
Outdoor exposure – plastic pipe placed in service or stored so that it is not protected from the elements of normal weather conditions, i.e., the sun's rays, rain, air and wind. Exposure to industrial and waste gases, chemicals, engine exhausts, etc. are not considered normal "outdoor exposure."
Permanence – the property of a plastic which describes its resistance to appreciable changes in characteristics with time and environment.
Plastic – a material that contains as an essential ingredient an organic substance of large molecular weight, is solid in its finished state, and, at some stage in its manufacture or in its processing into finished articles, can be shaped by flow.
Plastics pipe – a hollow-cylinder of plastic material in which the wall thicknesses are usually small when compared to the diameter and in which the inside and outside walls are essentially concentric. See plastics tubing.
Plastics tubing – a particular size of plastics pipe in which the outside diameter is essentially the same as that of copper tubing. See plastics pipe.
Polypropylene plastics – plastics based on polymers made with propylene as essentially the sole monomer.
Poly (vinyl chloride) – a resin prepared by the polymerization of vinyl chloride with or without the addition of small amounts of other monomers.
Poly (vinyl chloride) plastics – plastics made by combining poly (vinyl chloride) with colorants, fillers, plasticizers, stabilizers, lubricants, other polymers, and other compounding ingredients. Not all of these modifiers are used in pipe compounds.
Pressure – when expressed with reference to pipe the force per unit area exerted by the medium in the pipe.
Pressure rating – the estimated maximum pressure that the medium in the pipe can exert continuously with a high degree of certainty that failure of the pipe will not occur.
Primer – strong organic solvent, preferably tetrahydrofuran, used to dissolve and soften the joint surfaces in preparation for and prior to the application of solvent cement. Primer is usually tinted purple.
Quick burst – the internal pressure required to burst a pipe or fitting due to an internal pressure build-up, usually within 60 to 90 seconds.
Schedule – a pipe size system (outside diameters and wall thicknesses) originated by the iron pipe industry.
Self-extinguishing – the ability of a plastic to resist burning when the source of heat or flame that ignited it is removed.
Service factor – a factor which is used to reduce a strength value to obtain an engineering design stress. The factory may vary depending on the service conditions, the hazard, the length of service desired, and the properties of the pipe.
Solvent cement – in the plastic piping field, a solvent adhesive that contains a solvent that dissolves or softens the surfaces being bonded so that the bonded assembly becomes essentially one piece of the same type of plastic.
Solvent cementing – making a pipe joint with a solvent cement. See Solvent Cement.
Stress – when expressed with reference to pipe the force per unit area in the wall of the pipe in the circumferential orientation due to internal hydrostatic pressure.
Sustained pressure test – a constant internal pressure test for 100 hours.
Thermoplastic – a plastic which is thermoplastic in behavior. Capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature.
Vinyl Chloride Plastics – plastics based on resins made by the polymerization of vinyl chloride or copolymerization of vinyl chloride with other unsaturated compounds, the vinyl chloride being in greatest amount by weight.
Weld-orKnit-line – a mark on a molded plastic formed by the union of two or more streams of plastic flowing together.

ABBREVIATIONS
ASA – American Standards Association
ASTM – American Society for Testing and Materials
CPVC – Chlorinated Poly (Vinyl Chloride) plastic or resin.
IAPMO – International Association of Plumbing and Technical Officials
ISO – International Standards Organization
NSF – National Sanitation Foundation
PP – Polyproylene plastic or resin
PPI – Plastic Pipe Institute
PS – Product Standard when references to a specification for plastic pipe and fittings. These specifications are promulgated by the U.S. Department of Commerce and were formerly known as Commercial Standards.
PSI – pounds per square inch
PVC – Poly (Vinyl Chloride) plastic or resin
SPI – The Society of the Plastics Industry, Inc.

COLLAPSE PRESSURE - PVC DUCT

Graph I: Calculated Collapse Pressures with Safety Factor of 5, FABCO Type I Grade I PVC Seamless Duct (minimum wall) @ 70-75° F vs Length of Span/Nominal O.D.



The Sheet Metal & Air Conditioning Contractors' National Association (SMACNA) sponsored a physical testing program on both rectangular and round Type I Grade I PVC fabricated duct, as well as a theoretical analysis of the test work. Equations were developed for collapse pressures of varying I/D ratios (I = distance between reinforced stiffeners (inches) and D = OD (inches)) as well as for collapse of a very long tube. Round duct sizes ranged from 18" O.D. to 48" O.D. with wall thicknesses of .137" to .282". Test values correlated within a 10% range.

Fabco ran actual collapse tests on 4 sizes of extruded seamless duct from 6" through 12" with I/D ratios exceeding 10 which confirmed the values calculated from the very long tube equation. (Note: Collapse values for all sizes with ratios exceeding 10 approach values for a very long tube).

This graph can be utilized to determine reinforcement spacing distance for higher negative pressures than shown in the SMACNA publication(1) for the sizes and minimum wall thicknesses shown.

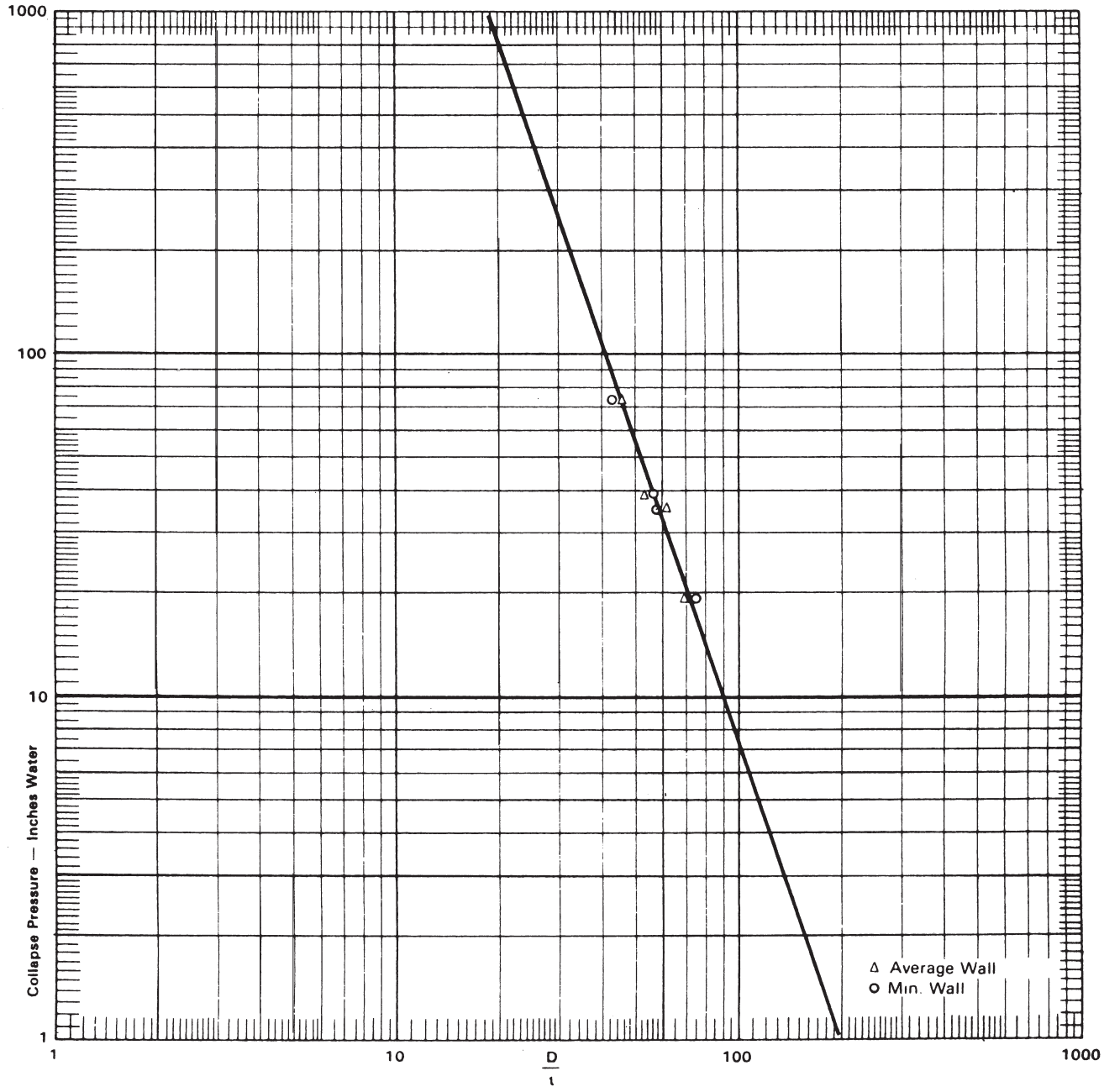
Example: 16" duct at 20" water I/D = 4

l = 16 x 4 = 64" between reinforcing stiffeners.

(1) Thermoplastic Duct (PVC) Construction Manual, SMACNA

COLLAPSE PRESSURE - PVC DUCT

**Graph II: Calculated Collapse Pressure with Safety Factory of 5,
FABCO Type I Grade I PVC Seamless Duct @ 70–75°F vs Nominal O.D./Wall**



This calculated collapse pressure graph with a safety factor of 5 for Type I Grade PVC duct has been experimentally confirmed for D/I ratios from 44-170. The 5-1 safety factor is believed to be sufficient for reasonable out of roundness due to storage and handling. Use of this graph for lower D/I ratios of Type I Grade I PVC pressure pipe should provide collapse pressures of greater than a 5-1 safety factor, since out of roundness will be appreciably less due to heavier walls of pipe produced under ASTM standards 1785 and 2241.

Use of minimum wall thicknesses as shown in Fabco's Specification for Duct and the ASTM Standards mentioned above are recommended when utilizing this graph for operating temperatures of 70° – 75° and below. Values of collapse pressures above 407" of water exceed a complete vacuum and should be considered as external collapse pressure. Conversion to PSI collapse pressure can be obtained by multiplying the inches of water by .0361; inches of water to inches of mercury by .07369.

Pump Data

I. STANDARDS FOR MEASURING HEADS AND CAPACITY.

Head is measured in feet, pounds per square inch (PSI), or in inches of mercury. However, so that a common means of head measurement is understood, it is recommended that all heads be expressed in feet of water. Measurement of liquid should be expressed in U.S. gallons.

II. ATMOSPHERIC PRESSURE.

At sea level it is 14.7 PSI. This will maintain a column of mercury 29.9 inches or a column of water 33.9 ft. high. This is the theoretical height of which water may be lifted by suction. The practical limit for cold water (60 F) is 25 feet.

III. SUCTION AND DISCHARGE HEAD.

1. Static Suction Lift – Is the vertical distance from the center line of the pump's suction inlet to the constant level of the water. This is added to discharge head to obtain total dynamic head.
2. Positive Suction Head – Is the vertical distance above the center line of the pump's suction to the constant level of the water. This is subtracted from the discharge head to obtain total dynamic head.
3. Dynamic Suction Head – Is the suction lift (or head) plus suction line friction loss. May be positive or negative.
4. Static Discharge Elevation – Is the vertical distance from the pump's discharge to the highest point in the discharge line.
5. TDH (Total Dynamic Head) – Is the total head and is the total of static suction lift (head), friction loss in suction line, static discharge elevation, friction loss in discharge line and fittings, plus discharge pressure, if any. To be hydraulically correct, we should not include "Static Head" in total dynamic head. Dynamic means "moving" and "Dynamic Head" only includes velocity head and friction loss. However, most pump people use TDH interchangeably with TH (Total Head).
6. Friction Head – Is the heat loss experienced by the movement of the liquid through the suction and discharge lines. Charts are available showing loss in feet of head at various flows through various pipe or hose sizes. Charts also show velocity in feet/sec, which is particularly important when pumping liquids with solids in suspension. Fittings, valves, etc. must be considered.

IV. NPSH.

Net Positive Suction Head is defined as head that causes liquid to flow through the suction line and enter the impeller eye. This head comes from either atmospheric pressure or from a static suction head plus atmospheric pressure. Two types of NPSH will be considered.

1. Required NPSH – Is a function of pump design. It varies between different makes, between different models, and with capacity of any one pump. This value is supplied by the manufacturer, if available. Refer to pump curves or contact the factory.
2. Available NPSH – Is a function of the system in which pumps operate. Can be calculated for any installation. For a pump to operate properly, available NPSH should be greater than the required NPSH, plus 2 feet for safety factor, at a desired head and capacity. In simple terms, available NPSH is calculated by deducting from barometric pressure, in feet, the static suction head (+ or -), friction loss, and the vapor pressure (ft.) of liquid being pumped. Velocity heads should also be deducted.

NPSH does not indicate the priming capabilities of self-priming centrifugal pumps. This capability is shown, generally on engine driven pumps, by respective "break-off" lines representing 10, 15, 20, 25' static suction lifts.

V. USEFUL FACTORS OR FORMULAS.

a) Feet head x .433 = PSI (pounds per square inch).
b) PSI (water) x 2.31 = Ft. Head
c) Specific gravity of water (sp.gr.) = 1.0.
d) PSI (water) x 2.31/sp.gr. = Ft. Head
e) Weight of one U.S. gallon of water = 8.33 pounds
f) One cubit foot (cu.ft.) of water contains 7.48 gallons.
g) GPM = Gallons Per Minute.
h) Imperial gallon x 1.2 = U.S. gallon; U.S. GPM x .833 = Imp. GPM.
i) TDH = Total Head or total dynamic head.
j) WHP = Water Horsepower.
k) BHP = Brake Horsepower.
I) EFF = Pump Efficiency.
m) WHP = Ft .Head x GPM/3960
n) BHP = WHP/EFF or BHP = Ft. Head x GPM/3960 x EFF (Pump)
o) EFF = WHP/BHP x 100
p) For liquids having different specific gravity other than 1.0.

WHP = Ft. Head x GPM x sp.gr./3960
BPH = Ft. Head x GPM x sp.gr./3960 x EFF

BHP (for liquids other than water) = BHP (for water) x sp.gr.

VI. EFFECT ON CENTRIFUGAL PUMPS ON CHANGE OF SPEED OR CHANGE OF IMPELLER DIAMETER.

Three rules govern the operation of centrifugal pumps:

a) Capacity varies directly with changes of speed or of the impeller diameter.
$GPM_1/GPM_2 = RPM_1/RPM_2$ or
$GPM_1/GPM_2 = Dia._1/Dia._2$

$GPM_2 = GPM_1/RPM_1 x RPM_2$ and
$GPM_2 = GPM_1/Dia._1 x Dia._2$

b) Head varies as the square of the speed or the impeller diameter.
$Head_1/Head_2 = RPM_1^2/RPM_2^2$ or $Head_1/Head_2 = Dia._1^2/Dia._2^2$
$Hd_2 = Hd_1/RPM_1^2/RPM_2^2$ and $Hd_2 = Hd_1/Dia._1^2/Dia._2$

c) Power (BHP) varies as the cube of the speed or impeller diameter
$BHP_1/BHP_2 = RPM_1^3/RPM_1^3$ or $BHP_1 = Dia_1^3/Dia_2^3$
$BHP_2 = BHP_1^3/RPM_1^3 x RPM_2^3$ and $BPH_2 = BHP_1^3/Dia._1^3 x Dia_2^3$

Pump Data

VII. EFFECT OF ALTITUDE ON PUMPS

At elevations above sea level, suction lift should be reduced accordingly to insure that the same amount of water can get into the pump as would occur at an equivalent sea level lift. Lower atmospheric pressure reduces horsepower output of gas engines, thus causing a drop in speed which reduces pump performance. Engine power will decrease 3.5% for each 1000 ft. above sea level and 1% for each 10°F above standard temperature at 60°F.

ATMOSPHERIC PRESSURE CONDITIONS ELEVATIONS ABOVE SEA LEVEL

Altitude Above Sea Level	Atmospheric Pressure Pounds/sq.in.	Barometer Reading Ins. of Mercury	Equivalent Head or Water, Ft.	Reduction to Max. Practical Dyn.Suction Lift
0	14.7	29.929	33.95	0 ft.
1000	14.2	28.8	32.7	1.2”
2000	13.6	27.7	31.6	2.3”
3000	13.1	26.7	30.2	3.7”
4000	12.6	25.7	29.1	4.8”
5000	12.1	24.7	27.9	6”
6000	11.7	23.8	27.0	6.9”
7000	11.2	22.9	25.9	8”
8000	10.8	22.1	24.9	9”

VIII. GUIDELINES FOR PUMPING WARM WATER

MAXIMUM PRACTICAL DYNAMIC SUCTION LIFTAND VAPOR PRESSURE

WATER CHARACTERISTICS

Altitude Above Sea Level	Atmospheric Pressure Pounds/sq.in.	Barometer Reading Ins. of Mercury	Equivalent Head or Water, Ft.	Reduction to Max. Practical Dyn.Suction Lift
0	14.7	29.929	33.95	0 ft.
1000	14.2	28.8	32.7	1.2”
2000	13.6	27.7	31.6	2.3”
3000	13.1	26.7	30.2	3.7”
4000	12.6	25.7	29.1	4.8”
5000	12.1	24.7	27.9	6”
6000	11.7	23.8	27.0	6.9”
7000	11.2	22.9	25.9	8”
8000	10.8	22.1	24.9	9”

IX. EFFECT OF SPECIFIC GRAVITY

The specific gravity of a substance is the ratio of the weight of a given volume to the weight of an equal volume of water at standard conditions.

1. A centrifugal pump will always develop the same head in feet no matter what the specific gravity of the liquid pumped; however, the pressure (in pounds per square inch) will be increased or decreased in direct proportion to the specific gravity.

2. The brake horsepower (BHP) of a pump varies directly with specific gravity. If the liquid has a specific gravity other than water (1.0), multiply the BHP for water by the sp.gr. of liquid handled.

X. VISCOSITY

The viscosity of a fluid is the internal friction or resistance to motion of its particles. The coefficient of viscosity of a fluid is the measure of its resistance to flow. Fluids having a high viscosity are sluggish in flow, for example: heavy oil or molasses. Liquids such as water or gasoline have relatively low viscosity and flow readily. Viscosity is a fluid property independent of specific gravity. Viscosities vary with temperature; as temperature increases, viscosity decreases. Pressure changes have negligible influence on viscosity. There are many types of viscometers and expressed in many terms. Commonly used is SSU (Seconds Saybolt Universal). This is actually the time in seconds required for a given quantity of fluid to pass through a standard orifice under standard conditions. Viscous liquids tend to reduce the capacity, head, and efficiency, and increase the BHP.

Kinematic Viscosity (in Centistokes)
= Absolute Viscosity (in centipoise)/Specific Gravity

Centistrokes = SSU/4.64

This is an approximation for Viscosities greater than 250 S.S.U.The approximated performance for pumping fluids more viscous than water is determined from the following formula:

$BHP_{vis} = Q_{vis} \times H_{vis} \times S.G./3960/E_{vis}$

HOW CENTRIFUGAL PUMPS WORK

Liquid is supplied to the inlet at the center of the pump head. Since centrifugal pumps are not self-priming, liquid must be supplied by gravity feed or the pump must be primed. The spinning impeller propels the liquid outward by centrifugal force, providing the motive force required to move the liquid. The specially shaped volute receives the liquid and converts the radial motion to a smooth pulseless flow. Easily adjust the flow rate by restricting the flow at the outlet.

CENTRIFUGAL PUMP TERMS

IMPELLER – A rotating vaned disck that provides the pumping force.
VOLUTE – The body of the pump that is shaped to receive liquid from the inlet and direct it through the outlet.

LIQUID PUMP TERMINOLOGY

HEAD – The ability of a pump to push a column of water vertically in a pipe. As the column lengthens, the flow rate decreases until the column's weight just balances the pump's force and there is no flow. This height is the total head (usually expressed as feet of head).

FLOW RATE – Usually expressed in gallons per minute (GPM) for large-volume pumps; in gallons per hour (GPH) for small-volume pumps.

DYNAMIC SEAL – Seal located at the shaft end of the pump drive.

HECK VALVE – Allows liquid to flow in one direction only. Generally used in discharge line to prevent reverse flow.

DEAD HEAD – Ability of a pump to continue running without damage when discharge is closed off. Only recommended with centrifugal pumps.

DENSITY (specific weight of a fluid) – Weight per unit volume, often expressed as pounds per cubic foot or grams per cubic centimeter.

FLOODED SUCTION – Liquid flows to pump inlet from an elevated source by means of gravity. Recommended for centrifugal pump installations.

FLOW – A measure of the liquid volume capacity of a pump. Given in gallons per hour (GPH), gallons per minute (GPM), liters per minute (I/min), or milliliters per minute (ml/min).

FLUIDS – Include liquids, gases, and mixtures of liquids, solids, and gases. For the purposes of this catalog, the terms fluid and liquid are both used to mean a pure liquid or a liquid mixed with gases or solids that acts essentially like a liquid in pumping applications.

FOOT VALVE – A type of check valve with a built-in strainer. Used at point of liquid intake to retain liquid in system, preventing loss of prime when liquid source is lower than pump.

HEAD – A measure of pressure, expressed in feet of head for centrifugal pumps. Indicates the height of a column of water being moved by the pump, assuming negligible friction losses.

PRESSURE – The force exerted on the walls of a container (tank, pipe etc.) by a liquid. Normally measured in pounds per square inch (psi) for positive displacement and metering pumps.

PRIME – A charge of liquid required to begin pumping action when liquid source is lower than pump. May be held in pump by a foot valve on the intake line, or by a valve or chamber within the pump.

SEAL – A device mounted in the pump housing and/or on the pump shaft, to prevent leakage of liquid from the pump. There are three types:

LIP – A flexible ring (usually rubber or similar material) with the inner edge held closely against the rotating shaft by a spring.
MECHANICAL – Has a rotating part and a stationary part with highly polished touching surfaces. Has excellent sealing capability and long life, but can be damaged by dirt or grit in the liquid.
PACKED – Multiple flexible rings mounted around the pump shaft and packed together by tightening gland nuts; some leaking is essential for lubrication.

RELIEF VALVE – Usually used at the discharge of a positive displacement pump. An adjustable, spring-loaded valve opens when a preset pressure is reached. Used to prevent excessive pressure buildup that could damage the pump or motor.

SEALLESS (MAGNETIC DRIVE) – No seal is used; power is transmitted from motor to pump impeller by magnetic force.

SELF-PRIMING – Refers to pumps that draw liquid up from below pump inlet (suction lift), as opposed to pumps requiring flooded suction.

SPECIFIC GRAVITY – The ratio of the weight of a given volume of liquid to the same volume of pure water. Pumping heavier liquids (specific gravity greater than 1.0) will require more drive horsepower.

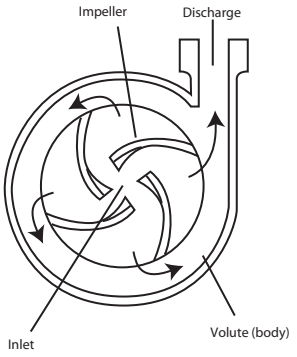
STATIC DISCHARGE HEAD – Maximum vertical distance (in feet) from pump to point of discharge with no flow.

STRAINER – A device installed in the inlet of a pump to prevent foreign particles from damaging the internal parts.

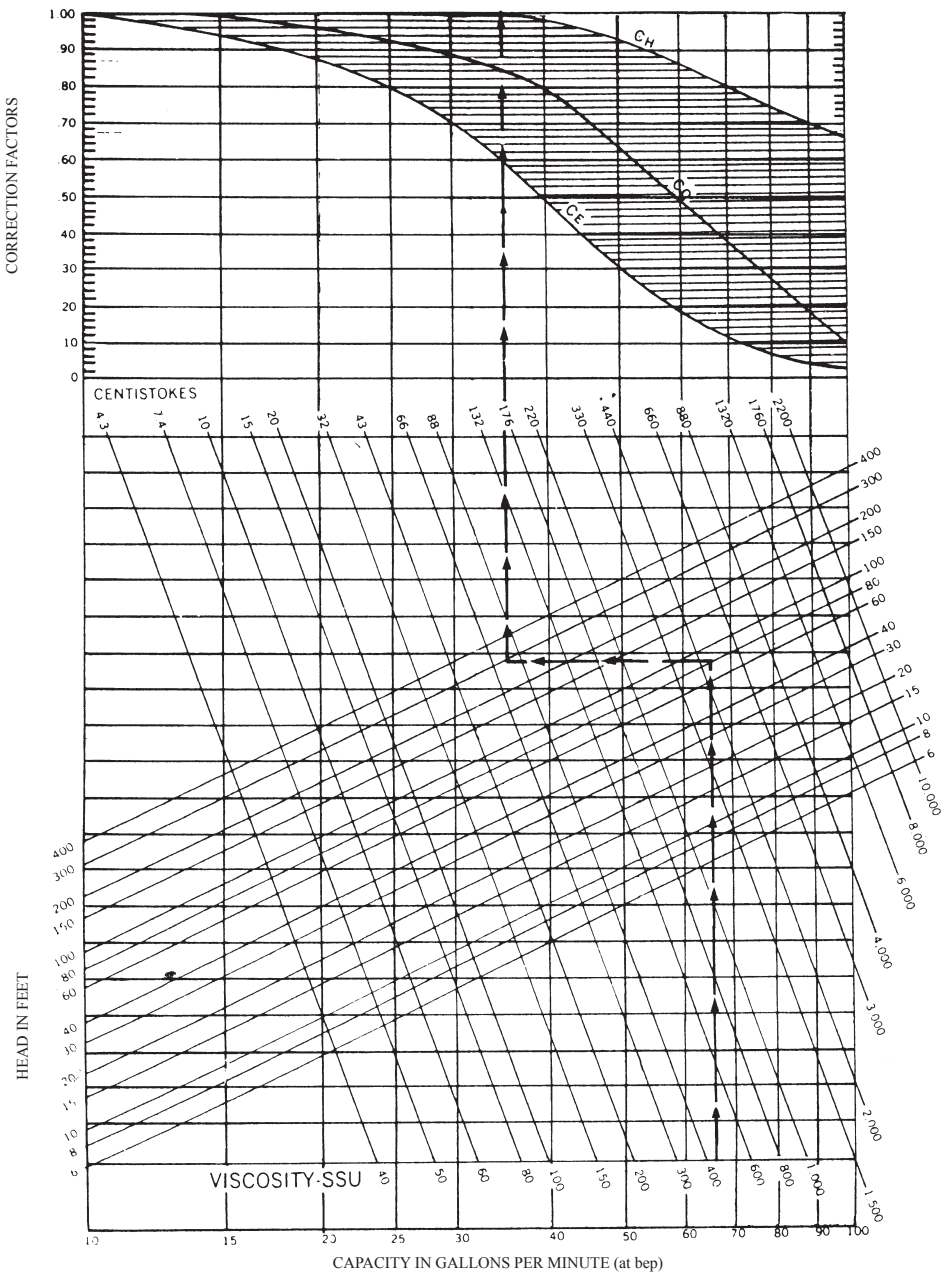
SUMP – A well or pit in which liquids collect below floor level sometimes refers to an oil or water reservoir.

TOTAL HEAD – Sum of discharge head, suction lift, and friction loss.

VISCOSITY – The "thickness" of a liquid, or its ability to flow. Most liquids decrease in viscosity and flow more easily as they get warmer.



PUMP DATA



VISCOSITY CORRECTION CHART

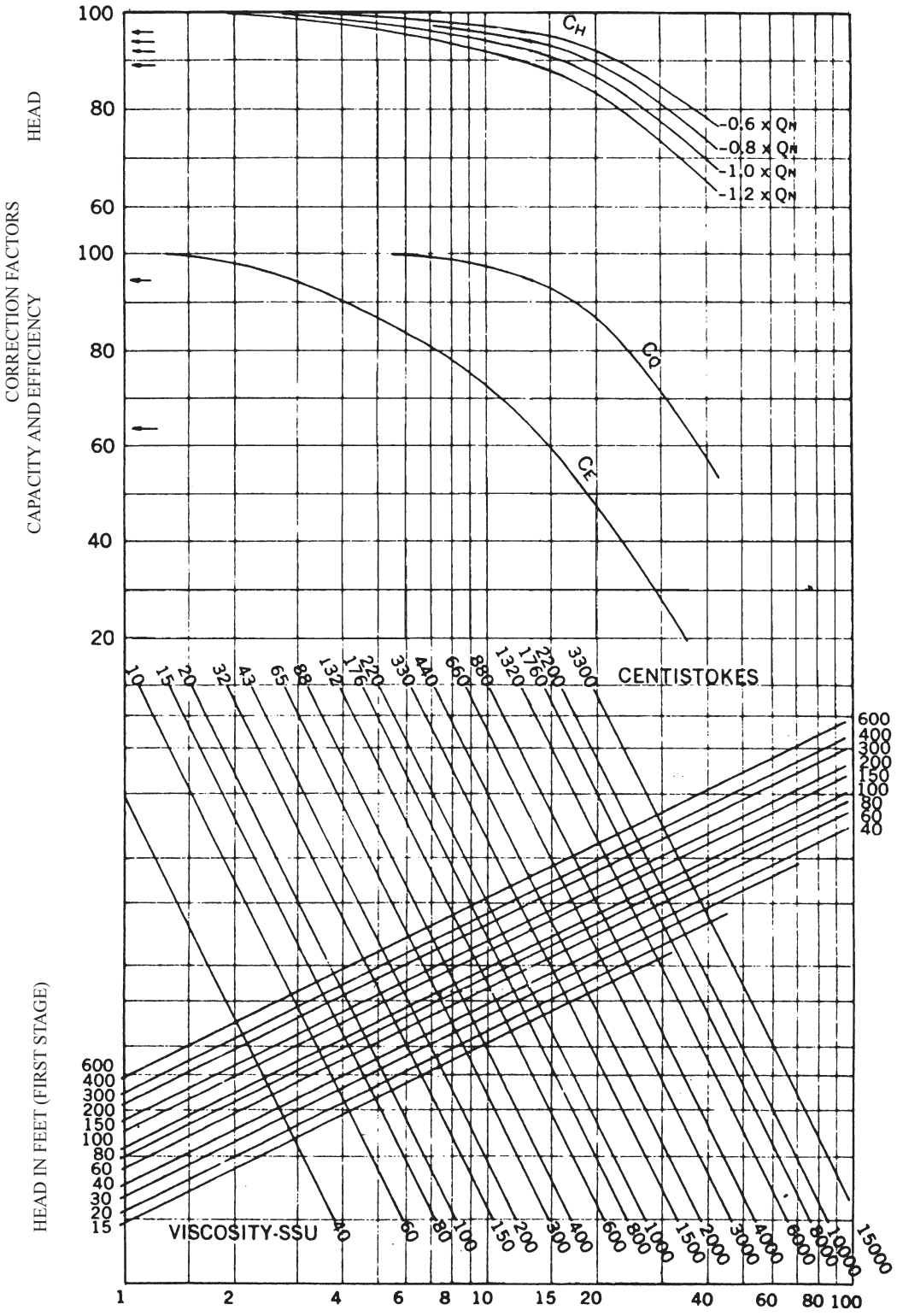
Example - Viscosity

Determine BHPvis when pumping 66 usgpm at 80 ft. of 50% NaOH with a pump at 48% Eff. with water.
*S.G. = 1.53 *Given from other tables
*Visc = 78cSt = 120 CP/1.53
Qw = 66 usgpm
H.W. = 80 ft.
E.W. = 48% = .48
Cq = .84)
Ch = 1.00) From above chart
Ce = .58
Qw x Cq = 66 x .84 = 55.44
Hw x Ch = 80 x 1.00 = 80.0
Ew x Ce = .48 x .58 = .2784
BHPvis = 55.44 x 80.0 x 1.53/3960/0.2784 = 6.16 H.P.

WHERE

BHPvis = Viscous brake horsepower
S.G. = Specific Gravity
3960 = Constant
Qw = Capacity pumping water (USGPM)
Cq = Capacity correction factor (Fig 1)
Qvis = Viscous Capacity (USGPM) = Cq X Qw
Hw = Head pumping water (ft.)
CH = Head correction factor (Fig 1)
Hvis = Viscous head (ft) = Ch X Hw
Ew = Efficiency pumping Water
Ce = Efficiency correction factor (Fig 1)
Evis = Viscous Efficiency = Ce X Ew
BHPvis = (cq X Qs) X (Hw X Ch) X S.G./3960/Ce/Evis

PUMP DATA



CAPACITY IN 100 GPM
PERFORMANCE CORRECTION CHART

Conversion Factors

- PHYSICAL DIMENSIONS - VOLUME

U.S. CUSTOMARY UNITS					S.I. UNIT	OTHER METRIC UNIT
cubic inch ($in.^3$)	US gallon (US gal)	Imp.gallon (Imp gal)	cubic foot ($ft.^3$)	barrel* (bbl)	cubic meter (m^3)	liter (l)
1	0.00433	0.00360	0.000579	0.000103	0.00001639	0.01639
231	1	0.8327	0.1337	0.0238	0.003785	3.785
277.42	1.2009	1	0.1606	0.0286	0.004546	4.546
1728	7.481	6.229	1	0.1780	0.02832	28.32
9702	42	34.97	5.615	1	0.15897	158.97
61.024	264.17	220	35.31	6.2898	1	1000
61.024	0.2642	0.2198	0.0353	0.00630	0.001	1

*By trade custom, one barrel petroleum oil is equal to 42 US gal.

CONVERSION TABLE - CAPACITY

U. S. CUSTOMARY UNITS					S.I. UNIT	OTHER METRIC UNITS	
Millions of US gallons per day (MGD)	US gallons per min (gpm)	Imp. gallons per min (Igpm)	cubic feet per sec (cfs)	*barrels per hr (bph)	cubic meters per sec (m3/s)	liters per min (l/min)	cubic meters per hr (m3/hr)
1	694.4	578	1.547	992	0.0438	2628	157.72
0.00144	1	0.8327	0.002228	1.4286	63.08×10^{-6}	3.785	0.2271
0.00173	1.2009	1	0.00268	1.7156	75.77×10^{-6}	4.5454	0.2728
0.64636	448.86	373.8	1	641.23	2.832×10^{-2}	1699	101.952
0.00100	0.7000	0.5829	0.00156	1	44.166×10^{-4}	2.6495	0.1590
22.824	15.852	13.188	35.316	22.643	1	60.000	3.600
0.000380	0.2642	0.2198	0.000586	0.3774	16.67×10^{-6}	1	0.0600
0.00634	4.4028	3.666	0.00981	6.2898	2.777×10^{-4}	16.667	1

*By trade custom, one barrel petroleum oil is equal to 42 US gal.

$gpm = \frac{0.1247}{w} \times lb/hr$ when w = density, lb/cu ft

CONVERSION TABLE-MASS, WEIGHT AND FORCE

Definitions:

1. Mass is absolute, the pound (lb) and kilogram (kg) are most commonly used units, the kilogram is the SI unit.

U.S. CUSTOMARY UNITS (avoirdupois)					S.I. UNIT	OTHER METRIC UNITS	
grain (gr)	ounce (oz)	pound (lb)	short ton	long ton	kilogram (kg)	gram (g)	metric ton
1	0.002286	-	-	-	-	0.0648	-
437.5	1	0.0625	-	-	0.02835	28.35	-
7 000	16	1	-	-	0.4536	453.6	-
-	-	2 000	1	.8929	907.2	-	0.9072
-	-	2 240	1.12	1	1016	-	1.016
15 432	35.27	2.205	-	-	1	1 000	0.001
15.432	0.03527	0.002205	-	-	0.001	1	-
-	-	2205	1.102	0.9842	1000	1 000 000	1

CONVERSION TABLE-POWER

U.S. CUSTOMARY UNITS			S.I. UNIT	OTHER METRIC UNITS	
foot-pounds per sec. (ft-lb/sec)	horsepower (hp)	British thermal units per sec (Btu/sec)	watts (W)	kilowatts (kW)	metric horsepower
1	0.00182	0.001285	1.356	0.001356	0.00184
550	1	0.7068	7.457×10^2	0.7457	1.014
778.2	1.415	1	1.055×10^3	1.055	1.434
0.7376	1.341×10^{-3}	9.478×10^{-4}	1	0.001	0.00136
737.6	1.341	0.9478	1000	1	1.360
542.5	0.9863	0.6971	7.355×10^2	0.7355	1

CONVERSION TABLE-PRESSURE

Units and symbols:

pounds per square inch (psi)
pascal (Pa) = 1 N/m (SI unit)
kilograms per square centimeter (kg/cm)
bar

1 psi = 0.0703 kg/cm^2 = 6894.76 N/m^2 = 6.894 kPa
1 kg/cm^2 = 14.22 psi = 9.80665×10^4 N/m^2 = 98.0665 kPa
1 atmosphere = 14.7 psi = 1.0332 kg/m^2 = 10.13×10^4 = 101.3 kPa
1 metric atmosphere = 98.0665 kPa
1 pascal = 1.45×10^4 psi = 1.02×10^5 kg/cm^3
1 bar = 10^5 Pa = 100 kPa

INDEX

Symbols

60 Series Hot Tap Ph / ORP Sensors 5-3
500 Series Combination Ph / ORP Sensors 5-5
2200D Dissolved Oxygen Controller 5-10
2850 Conductivity Sensor 5-12
3200U Ultrasonic Flow/Level Monitor 5-8
8760CLP Chlorine & Ph Analyzer 5-6

A

A-100N Peristaltic Pumps 6-28
A-1600 Flexflo® Peristaltic Pumps 6-29
Acrylic Sheet 4-14
Actuated Valve 3-16–3-24
Am Series Hot Tap Ph /ORP Sensors 5-4
Angle Valves 3-8
Aquametrix 60 Series Ph /ORP Sensors 5-2
Aquametrix 2200P Controller 5-1
Aquametrix Shark-120/240 Controller 5-1
Aquametrix Shark Tx/Txp Transmit 5-1
Autotherm Temperature Regulated Welding Gun 4-36
AVFM-II Area Velocity Flow Level Monitor 5-9

B

Bag Filters 6-18
Ball Check Valves/Foot Valves 3-10
Basket Strainers 6-22
BCF® Plus Fusion Machine 2-18
Black Hdpe And Nylon Insert Fittings 8-17
Bolted Flange Bulkhead Fittings 7-12
Bolted Flange Fittings 7-12
Buffer Solutions 5-20
Butterfly Valves 3-4–3-5

C

C3 Series Chem-Protm Diaphragm Pumps 6-31
C-600P Chem-Feed Diaphragm Pumps 6-31
C-1100 Chem-Feed Diaphragm Metering Pumps 6-29
C-1500N Chem-Feed Diaphragm Metering Pumps 6-30
Calibrated Needle Valves 3-8
Calibration And Buffer Solutions 5-20
Cam Couplers 8-12
Cartridge Filters 6-20
Catalyst Support 9-13
Cement 1-21
Centrifugal Pumps 6-3, 6-7
Check Valves 3-10
Chemical Resistance Chart For Snyder Tanks 7-9
Chemkor Butterfly Valves 3-4
Chemkor CPVC Pipe 1-15
Chemkor Gear Box Butterfly 3-4
Chemkor Schedule 80 PVC Pipe 1-1
ChemkoR Schedule 40 Gray PVC Fittings 7, 1-8
Chemkor Schedule 40 Gray Pipe 6
Chemkor Schedule 40 White PVC Fittings 1-10, 1-11
Chemkor Schedule 40 White PVC Pipe 1-9
Chemkor Schedule 80 CPVC Fittings 1-16 to 1-19
Chemkor Schedule 80 PVC Fittings 1-2, 1-3, 1-4, 1-5
Chemkor Schedule 80 PVC Pipe 1-1
Chemkor Single Union Ball Valves 3-1
Chemkor Super Bloc True Union Ball Valves 3-1
Chemtrol True Union Ball Valves 3-2
Chlorine Analyser 5-6, 5-18
Clamp-It PVC Tapping Saddles 1-23
Clear Braided PVC Hose 8-3
Clear PVC Hose 8-2
Clear PVC Pipe 1-12
Clear PVC Sheet 4-5
Closed Top Tanks 7-5
Column Internals 9-14
Compact Econo Ball Valves 3-6
Composolite® Fiberglass Building System 4-30
Conductivity Sensor 5-6
Conductivity Sensors 5-12
Conical Bottom Tanks 7-8
Controller, pH, ORP, Conductivity 5-1
Controller, Oxygen 5-10
Conventional Butt Fusion Machine 2-19
CPVC Fittings 1-16–1-19
CPVC Pipe 1-15
CPVC Sheet 4-7
CPVC Ventillation Duct Pipe 9-9

D

DFM-4.0 Doppler Flow Monitor 5-8
Door Strips 4-17
Double Wall Containment Tanks 7-6
Dual Containment Pipe 2-8
Duct Fittings 9-2
Duct Pipe 9-1, 9-4, 9-5, 9-8, 9-9
Duranit® Catalyst Support 9-13
Durashield® Foam Core Building Panels 4-30

E

Eductors 6-25
Energy-Saving Hollow Balls 9-15
Es Series Conductivity Sensors 5-6
Expansion Joints, PVC CPVC 1-24

INDEX

F

F300 - Pitot Tube Acrylic Flowmeters 5-21
F-400N Machined Acrylic Tube Flowmeter 5-22
F-410N Machined Acrylic Tube Flowmeter 5-23
F-420N MachiNed Acrylic Tube Flowmeter 5-24
F-430N Machined Acrylic Tube Flowmeter 5-25
F-440 Polysulfone Flowmeter 5-27
F-450 Polysulfone Flowmeter 5-28
F-550 Machined Acrylic Block Flowmeter 5-26
F-1000 Digital Paddlewheel Flowmeter 5-29
F-2000 Digital Paddlewheel Flowmeter 5-31, 5-32
Fabco Eliminator Type LTH 2000 9-17
Fabco Eliminator Type LTV 1500 9-17
Fabcograte FRP Grating 4-21, 4-22, 4-23
Fabco Round Welding Rod 4-13
Fabco Specialty Tubing 8-8
Fast & Tite Tube Fittings 8-15
Fiberglass Structural Shapes And Plate 4-26 to 4-28
Fiberglass Threaded Rod And Nuts 4-38
Filter Cartridges 6-5, 6-12–6-13
Filter Chambers 6-10
Filterchem Level & Pump Controls 5-17
Filterchem Mini-Stat Level Control 5-17
Fire Retardent PP Ventillation Duct Pipe 9-8
Fittings, Bulk Head 7-12
Fittings, Clear PVC 1-13
Fittings, CPVC 1-16–1-19
Fittings, LXT 2-3
Fittings, Metric 1-14
Fittings, PP 1-27
Fittings, PP 1-26
Fittings, PVC 1-2
Fittings, PVDF 1-29
Fittings, Self Aligning 7-12
Fittings, Tube 8-16
Fittings, White PVC 1-10
Flange Gaskets 1-24
Flexible PVC Door Strips And Sheet 4-17
Flexible Tubing 8-10
Flexi-Joint Connections 7-12
Flex-Pro^{tm} Peristaltic Pumps 6-27
Flowline Contact Level Sensors 5-16
Flowline Echopod 5-15
Flowline Echosafe 5-15
Flowline Echospan 5-16
Flowline Echoswitch Ii 5-16
Flowline Echotouch 5-15
Flowmeters 5-21–5-29
Flow Monitors 5-8
Flow Sensor 5-7
Flow Sensors 5-14
Foot Operated Valves 3-12
FRP Grating 4-21
FRP Handrails 4-29
FRP Plate 4-29
FRP Structural Shapes 4-26
Fuseal Schedule 40 Polypro Pipe 2-5
Fuseal Schedule 80 25/50 PVDF Pipe 2-7
Fuseal Schedule 80 Polypro Pipe 2-6
Fusion Machines 2-18–2-20

G

Gaskets 1-24
Gate Valves 3-9
GF 375 True Union Ball Valves 3-2
GF 546 True Union Ball Valves 3-3
GF 568 Gearbox Butterfly Valves 3-5
GF Contain-It 2-8
GF Electric Actuated Ball Valve 3-17, 3-18
GF Electric Actuated Butterfly Valve 3-18
GF Manual Diaphragm Valve 3-21
Gf Metric PVC Fittings 1-14
GF Pneumatic Actuated Ball Valve 3-16
GF Pneumatic Actuated Butterfly Valve 3-19
GF Pneumatic Actuated Diaphragm Valve 3-20
GF Type 304 Y-Check Valves 3-10
GF Type 567 Butterfly Valves 3-5
GF V182/V82 Pressure Regulating Valve 3-15
GF V185/V85 Pressure Relief Valve 3-14
GF V186/V86 Pressure Retaining Valve 3-15
GF V782 Pressure Reducing Valve 3-14
GF V786 Pressure Retaining Valve 3-13
Glass Backed Sheet 4-15
Globe Valves 3-9
Grating Accessories 4-25
Grating, FRP 4-21
Grating, Pultruded 4-24
Guidelines For Factory-Installed Fittings 7-13
GVS-65 Gas Venting System 2-1

H

Hanna HI504 pH/ORP Controller 5-18
Hanna HI700 EC Controller 5-18
Hanna Industrial Probes 5-19
Hanna Multi Parameter Meter 5-20
Hanna pH, ORP, Free/Total Chlorine Analyser 5-18
Hanna Pocket Testers 5-19
Hayward 4200 Cartridge Filters 6-20
Hayward Bus Control System 3-22
Hayward Duplex Basket Strainers 6-23
Hayward EAU Electric Actuator 3-24
Hayward EJM Reversing Actuator 3-24

INDEX

Hayward EVR Electric Actuator 3-24
Hayward EVS/EVT Electric Actuator 3-23
Hayward Filter Bags 6-12
Hayward FLT Series CartridGe Filters 6-5
Hayward PAD/PAS Pneumatic Actuator 3-22
Hayward PCD/PCS Pneumatic Actuators 3-23
Hayward PKD/PKS Pneumatic Actuator 3-23
Hayward Plastic Y-Strainers 6-21
Hayward PMD/PMS Pneumatic Actuator 3-22
Hayward PP/PVDFSimplex Bag Filter 6-19
Hayward PVC/CPVC/PP Duplex Bag Filter 6-19
Hayward PVC/CPVC Simplex Bag Filter 6-18
Hayward Simplex Plastic Basket Strainers 6-22
Hayward Strainers Baskets 6-24
Hayward TB Series True Union Ball Valves 3-3
HDPE Insert Fittings 8-17
HDPE Pipe 2-9
HDPE Sheet 4-10
Headers 5-34
Heatflon® Immersion Heating Panels 9-16
Heating Panels 9-16
Heavy Duty Tank Adapters 7-11
HF Thermoplastic Centrifugal Fans 9-18–9-20
High Density PE Sheet 4-10
High Pressure Lay-Flat Discharge Hose 8-14
Hollow Balls 9-15
Horizontal Closed Top Tanks 7-7
Hose, Abrasion Resistant 8-5
Hose Clamps 8-9
Hose, Clear Braided 8-3
Hose, Clear PVC 8-2
Hose, Lay Flat 8-14
Hose, PVC 8-5
Hose, PVC Transfer 8-4
Hose, Spa 8-1
HDPE Pipe 2-9, 2-10, 2-11, 2-12

I

Immersion Heating Panels 9-16
Insert Fittings 8-17
Instaduct® Cpvc Ventillation Duct Pipe 9-9
Instaduct® Pvc Ventillation Duct Fittings 9-2–9-3
Instaduct® Pvc Ventillation Duct Pipe 9-1, 9-4, 9-5
In-Tank Filtration Systems 6-6, 6-15
IP80 Series Paddle Wheel Flow Sensors 5-7
IP100 Series Paddle Wheel Flow Sensors 5-7
IR Plus™ Fusion Machine 2-18

K

K3130 Series BF Heavy Wall Pvc Hose 8-5
Kuri-Tec Clear Braided PVC Hose 8-3
Kuri-Tec Clear PVC Hose 8-2

L

Laboratory Ball Cock Valve - Type 324 3-6
Laboratory Grade PP TubIng 8-7
Laramy 30-10 Basic High Speed Torch 4-33
Laramy 30-102 Fabricating Torch 4-33
Laramy 30-200 Torch And Compressor 4-33
Laramy Custom Welding Tips 4-35
Laramy Economy Compressor/Torch 4-34
Laramy Plastic Bending Bars 4-34
Laramy Universal High-Speed Tip 4-35
Laramy Vari-FT/RS Self Contained Torch 4-34
Large Diameter Swing Check Valves 3-11
Lay-Flat Discharge Hose 8-14
LDPE Sheet 4-11
Level Monitors 5-8
Level Sensor 5-14
Level Transmitter 5-14
Level Transmitters 5-15
Lexan Sheet 4-14
Liquid Dispensing Assemblies 3-13
Low Density Pe Sheet 4-11
LXT Schedule 80 Fittings 2-3
LXT Schedule 80 Pipe 2-2
LXT Valves And Accessories 2-4

M

Mag Drive Pumps 6-4, 6-8
Mazzei Injectors 6-26
Mcelroy 824 Fusion Machine 2-20
Metering Ball Valves - Type 323 3-6
Metering Pumps 6-27–6-32
Micro-Flo Digital Flowmeter 5-33
Mini-Max Level Control 5-17
Mist Eliminator 9-17
Mixers 6-9
Model 75 1/2" - 2" Fusion Tool 2-19
MSA250-SE Electrofusion Machine 2-19
MS Series Conductivity Sensors 5-6
Multi Parameter Meter 5-20

N

Natural Polypropylene Pipe 1-25
Natural Polypropylene Schedule 80 Fittings 1-26, 1-27
Natural Pvdf Fittings 1-30
Nylon Cable Ties 8-13
Nylon Insert Fittings 8-17

INDEX

O

Open Top Cylindrical Tanks 7-2
Open Top Rectangular Tanks 7-3, 7-4
ORP Probe 5-2
ORP Controllers 5-18
ORP Probes 5-11
Other Plastic Rod 4-19

P

P91 Dissolved Oxygen Probe 5-10
Packing 9-13
Packing 9-10, 9-11
Penguin A-A In-Tank Filtration Systems 6-15
Penguin A-B In-Tank Filtration Systems 6-15
Penguin A In-Tank Filtration SystemS 6-15
Penguin A-SF In-Tank Filtration Systems 6-17
Penguin BF In-Tank Filtration Systems 6-17
Penguin CB Filter Bag Chambers 6-11
Penguin CN In-Tank Filter Chambers 6-10
Penguin CT Carbon Treatment Chambers 6-11
Penguin HF In-Tank Filtration Systems 6-16
Penguin Horizontal Centrifugal Pumps 6-7
Penguin Horizontal Volute Pump 6-8
Penguin Magnetic Drive Pump 6-8
Penguin MF In-Tank Filtration Systems 6-16
Penguin Mixers 6-9
Penguin MR Precious Metal Recovery System 6-14
Penguin PE Penductor SpargIng Eductors 6-25
Penguin PF Wound Filter Cartridges 6-12
Penguin PGG Pressure Gauges And Guards 6-9
Penguin PP Pleated Filter Cartridges 6-13
Penguin Sealless Vertical Pumps 6-7
Penguin Series C Filter Chambers 6-10
Penguin Series PC Carbon Filter Cartridges 6-13
Penguin Series PES Penductor Systems 6-25
Penguin Series PS Filter Sleeves 6-12
Penguin Sm In-Tank Filtration Systems 6-16
Penguin SR Precious Metal Recovery System 6-14
Penguin VF In-Tank Filtration Systems 6-17
Perforated Sheet 4-16
PE Tubing 8-6
Ph Controllers 5-18
Ph Probe 5-2
Ph Probes 5-11, 5-19
Pipe, Acid Waste 2-5–2-7
Pipe, Core Sampling 2-13
Pipe, CPVC 1-15
Pipe, Dual Containment 2-8
Pipe, Fuseal 2-5, 2-6, 2-7
Pipe, Gas Vent 2-1
Pipe, HDPE 2-9
Pipe, LXT 2-2
Pipe, PP 1-25
Pipe, PROGEF PP 2-14
Pipe, PVC 6
Pipe, PVC 1-1
Pipe, PVC S40 6
Pipe, PVC White 1-9
Pipe, PVDF 1-28
Pipe, SDR 1-20
Pipe, SYGEF PVDF 2-16
Plastic Bolts, Nuts And Washers 4-39
Plastic Fans 9-18–9-20
Plastic Fans 9-18
Plastic Liner / Core Sampling Pipe 2-13
Plastic Packing 9-10, 9-11
Plastic Rings 9-12
Plastic Saddles 9-12
Plexiglas Sheet 4-14
Pocket Testers 5-19
Polycarbonate Sheet 4-14
Pool And Spa Hose 8-1
PP Cam Coupler Fittings 8-12
PP Fittings 1-26, 1-27
PP Pipe 1-25
PP Sheet 4-8
PP Sheet, Copolymer 4-9
PP Tubing 8-7
PP Ventillation Duct Pipe 9-8
Precious Metal Recovery System 6-14
Pressure By-Pass Valves 3-12
Pressure Gauges 6-9
Pressure Regulators 3-12
Pressure Relief Valves 3-12
Pressure Sensors 5-13
Pressure TransMitter 5-12
Pressure Valves 3-12
Primer 1-21
Probe, ORP 5-2
Probe, pH 5-2
Probes, ORP 5-11
Probes pH 5-11
Probes, pH 5-19
PROGEF® Natural PP Piping System 2-15
PROGEF STD (Beta PP) Piping System 2-14
Pultruded Grating 4-24
Pumps, Centrifugal 6-7
Pumps, Centrifugal 6-3
Pump Selection Guiide 6-32
Pumps, Mag Drive 6-4
Pumps, Mag Drive 6-8
Pumps, Metering 6-27
Pumps, Vertical Immersible 6-1

INDEX

PVC And CPVC S80 Expansion Joints 1-24
PVC And CPVC Shapes 4-20
PVC Chemcock Valves 3-8
PVC Fittings 1-2–1-5
PVC Fittings, Clear 1-13
PVC Fittings, Gray 1-7
PVC Fittings, Metric 1-14
PVC Fittings, White 1-10
PVC Gate Valves 3-9
PVC Globe Valves 3-9
PVC Hose Insert Fittings 8-11
PVC Pipe 1-1, 1-6
PVC Pipe,Clear 1-12
PVC Pipe, Sdr 1-20
PVC Rod 4-18
PVC SDR Pressure Pipe 1-20
PVC Sheet 4-1
PVC Sheet, Clear 4-5
PVC Ventillation Duct Fittings 9-2, 9-2–9-3
PVC Ventillation Duct Pipe 9-1, 9-4, 9-5
PVDF Fittings 1-29–1-30
PVDF Natural Sheet 4-16
PVDF Pipe 1-28
PVDF Schedule 80 Pipe 1-28

R

Rectangular Tanks 7-3
Red PVDF Fittings 1-29
Ring Packing 9-12
Rings 9-12
Risers 5-34
Riser Supports 5-34
Rod, Other 4-19
Rod, PVC 4-18
Rod, UHMW 4-18
Rod, Welding 4-13

S

Saddles 1-23, 9-12
Saddles Packing 9-12
Safplate® Fiberglass Gritted Plate 4-29
Safrail™ Fiberglass Ladders 4-30
Safrail™ Industrial Fiberglass Handrails 4-29
Schedule 40 Clear PVC Fitting 1-13
Schedule 80 Pipe 1-1
Self Aligning Ball Dome Fitting 7-12
Series E Instrument Grade Pe Tubing 8-6
Series K7130 Heavy Wall PVC Transfer Hose 8-4
Series K7160 Standard Wall PVC Hose 8-4
Series UBK Abrasion-Resistant PVC Hose 8-5
SG 110 Socket Fusion Machine 2-18
Shapes, PVC And CPVC 4-20
Shark 5-1
Sheet, Acrylic 4-14
Sheet, Clear PVC 4-5
Sheet, Copolymer PP 4-9
Sheet, CPVC 4-7
Sheet, Glass Backed 4-15
Sheet, HDPE 4-10
Sheet, LDPE 4-11
Sheet, Lexan 4-14
Sheet, Perforated 4-16
Sheet, Polycarbonate 4-14
Sheet, PP Homopolymer 4-8
Sheet, PVC 4-1–4-2
Sheet, PVDF 4-16
Sheet, UHMW 4-12
Signet 2250 HydrostraTic Level Sensor 5-14
Signet 2350 Temperature Sensor 5-13
Signet 2450 Pressure Sensor 5-13
Signet 2724-2726 pH/ORP Electrodes 5-11
Signet 2754-2757 pH/ORP Electrodes 5-11
Signet 2819-2823 Conductivity Electrodes 5-12
Signet 8250 Level Transmitter 5-14
Signet 8350 Temperature Transmitters 5-13
Signet 8450 Pressure Transmitter 5-12
Signet 8900 Multi-Parameter Controller 5-11
Signet Flow Sensors 5-14
Simona® Clear PVC Sheet Technical Data 4-6
Simona® Copolymer PP Sheet 4-9
Simona® Cpvc Corzan® Sheet 4-7
Simona® Homopolymer PP Sheet 4-8
Simona® Plastic Rod 4-18
Simona® Pvc Type II Sheet Technical Data 4-4
Simona® Pvc Type I Sheet 4-1
Simona® Pvc Type I Sheet Technical Data 4-2
Simona® Versadur® Clear Pvc Sheet 4-5
Simona® Versadur® Pvc Type II Sheet 4-3
Small Open Top Cylindrical Tanks 7-1
Solvent Cement And Primer 1-22
Solvent Cement And Primer 1-21
Spa Hose 8-1
Spray Nozzles 5-35
Spx Series Paddle Wheel Flow Sensors 5-7
Stingray Level & Velocity Logger 5-9
Strainers, Basket 6-22
Strainers, Y 6-21
Super C Compact Ball Valves 3-6
Swing Check Valves 3-11
SYGEF® PLUS PVDF Piping System 2-17
SYGEF® STD PVDF Piping System 2-16

INDEX

T

Tank Adapters 7-11
Tank Adaptersd 7-11
Tank Fittings And Adapters 7-11
Tank Resin Selection Guide 7-10
Tanks, Closed Top 7-5, 7-7
Tanks, Conical Bottom 7-8
Tanks, Containment 7-6
Tanks, Open Top 7-1
Tanks, Rectangular 7-3
Tapping Saddles 1-23
Temperature Sensor 5-13
Temperature Transmitters 5-13
Thermoplastic Centrifugal Fans 9-18
Three Way Ball Valves 3-7
Tiger-Flex® Pool And Spa Hose 8-1
Tracstar® 630 Fusion Machine 2-20
Transferlox® Plastic Saddles 9-12
Transferpack® Plastic Rings 9-12
Transition Unions 1-23
Tri-Packs® Plastic Packing 9-10, 9-11
Trueseal™ Thermoplastic Tube Fittings 8-16
Tube Fittings 8-16
True Union Ball Valves 3-1–3-3
Tube Fittings 8-15, 8-16
Tubing, PE 8-6
Tubing, PP 8-7
Tubing, Specialty 8-8
Type 343 Horizontal Three Way Ball Valves 3-7
Type 343 Vertical Three Way Ball Valves 3-7

U

UHMW Rod 4-19
UHMW Sheet 4-12
Ultra High Molecular Weight (UHMW) Sheet 4-12
Uni-Spray Headers 5-34
Uni-Spray Nozzles 5-35
Uni-Spray Risers 5-34
Uni-Spray Riser Supports 5-34
Universal Ball Dome Fittings 7-12

V

Valves 3-1–3-3, 3-8
Valves, Actuated 3-16
Valves, Butterfly 3-4–3-5
Valves, Check 3-10
Valves, Gate 3-9
Valves, Globe 3-9
Valves, LXT 2-4
Valves, Pressure 3-12
Valves, Three WaY 3-7
Valves, True Union 3-1
Ventillation Duct Pipe 9-1, 9-4, 9-5, 9-8, 9-9
Vertical Closed Top Tanks 7-5
Vertical Pumps 6-7
Verticle Immersible Pumps 6-1

W

Wafer Check Valve 3-11
Webster C5, C7, C8 And C10 Centrifugal Pumps 6-3
Webster D Series Immersible Pumps 6-4
Webster In-Tank Filtration Systems 6-6
Webster R Series Mag Drive Pumps 6-4
Webster S12/S16 Immersible Pumps 6-2
Webster S Series Immersible Pumps 6-1
Webster S Series Quick Service Pumps 6-2
Wegener Airtherm Hot Air Welding Gun 4-36
Wegener Duratherm Hot Air Welding Gun 4-36
Wegener Exweld Alpha2 EC Extrusion Welder 4-37
Wegener Exweld Beta2 EC Extrusion Welder 4-37
Wegener Exweld Gamma2 EC Extrusion Welder 4-37
Wegener Exweld Mini-F Extrusion Welder 4-37
Wegener Spark Testers 4-35
Welding Guns And Accessories 4-31–4-39
Welding Rod 4-13
White PVC Pipe 1-9

Y

Y Pattern Valves 3-8
Y Strainers 6-21

Z

Zinzer Jumbotherm Welding Gun 4-31
Zinzer Unitherm Welding Gun 4-31
Zinzer Welding Accessories 4-32

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